THE

FOUNDRY TRADE JOURNAL

WITH WHICH IS INCORPORATED

THE IRON AND STEEL TRADES JOURNAL

VOL. 55 Thursday, September 3, 1936 No. 1046

PUBLISHED WEEKLY

Subscription Terms: 15s. per annum.
Foreign and Colonial: 17s. 6d. per annum.
All Subscriptions are payable in advance.

All Communications to be addressed to the Editor, the Advertisement Manager, or the Publisher of

THE FOUNDRY TRADE JOURNAL,
49, WELLINGTON STREET, LONDON, W.C.2

Telegraphic Address: "Zacatecas, Rand, London."
Telephone: Temple Bar 3951 (5 lines).

THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF

The Institute of British Foundrymen
The Institute of Vitreous Enamellers
The National Ironfounding Employers' Federation
The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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Impact Testing and Cast Iron

That cast iron is not commonly used for parts which have to resist impact or sudden shock is perhaps one, if not the principal reason why more attention has not been paid to its impact resistance and methods for determining this. The advent of high-duty cast irons, alloy cast irons, and cast irons amenable to heat treatment has extended its use considerably, and engineers have adopted it for use in parts hitherto unthought of, and in some cases these uses have exposed cast iron to impact and vibratory stresses, and have rendered it necessary for some means by which toughness and resistance to impact can be estimated between various types of iron.

Cast iron being an inherently brittle material, it was not to be expected that the methods of determining impact resistance, which have been found successful with ductile materials and particularly with steels, and which have long been standardised and incorporated in specifications for such materials, would be adaptable for cast iron. Experiments have proved this to be more or less true, and have necessitated the modification of such tests. It cannot be said, however, that a satisfactory method of impact testing has been determined for cast iron, which could be adopted and included in a specification.

Single blow tests with machines of the Izod and Charpy types have given results of a comparable nature when large unnotched test specimens are used, and comparable results have also been obtained with drop impact testing machines and large specimens, and the results obtained from both tests have been found to show a relationship to the resilience of cast iron as determined by the transverse test. Repeated impact tests are of a different character, and according to the testing conditions can be made to approach either the single blow test on the one hand or the fatigue test on the other. The repeated impact test used by the British Cast Iron Research Association has been constructed to avoid the two extremes, and gives results from which the relative toughness or resistance to shock of cast irons can be estimated in the same order as obtained from actual practical experience. Little data have been published of results obtained with this test, and it was with pleasure that we observed in the British exchange Paper to the French Association, published in the August 20 issue of the FOUNDRY TRADE JOURNAL, a series of repeated impact tests on various types of cast irons, and an attempt to correlate the results obtained with the results obtained from transverse stress-strain curves.

Most of the systematic work published on the impact testing of cast iron has been the work of American investigators. The experiments of the Sub-Committee of the American Society for Testing Materials, under the chairmanship of Dr. J. T. MacKenzie, explored a wide field and made extensive tests, including thirteen types of impact test on a large number of cast irons. A large proportion of their report is devoted to correlating the results obtained from those impact tests with the results obtained from other physical tests. A more recent American investigation has dealt with the impact resistance and other physical properties of some sixty cupolas and electric furnace alloy cast irons. Both investigations have been of an extensive nature and have supplied useful and valuable information, and, at the same time, have shown that more work is still required on the impact testing and impact resistance of cast iron, before definite and reliable conclusions can be postulated.

Casting-Consciousness—II

We suggested last week that since research is expanding the applications of cast iron, and propaganda for pressings, weldings and plastics tends to concentrate upon deficiencies in the material most manifested by the less enterprising manufacturers, there is room for an organisation, the primary object of which would be to carry out propaganda for the founding industry, in the same way as it is carried out by various bodies for the non-ferrous metals.

It will have been noted that there are separate bodies for the non-ferrous metals, but it does not by any means follow that separate bodies would be needed for the divisions of the founding industry. There are several reasons for this. In the first place, the existing technical, research and educational bodies are not affected by any such divisions, and any new activity would be linked with them. Secondly, an attempt was made in the U.S.A. to create such a body exclusively for grey iron, and it seems to have been dissolved, although the depression may have accounted for that. Thirdly, a number of makers and users are interested in more than one of the divisions to which we refer, grey iron, white or chilled iron, malleable cast iron and steel. (The question of non-ferrous castings is more debatable, and they are probably covered severally by the existing bodies to which we have referred.) Fourthly, the distinction between these branches becomes increasingly difficult to define from the technical point of view.

(*Concluded on page* 172.)

Flame-Cutting of Metals

MR. H. H. MOSS, in the course of an article on "Metallurgical Cutting for Fabrication Repair or Demolition," in "Mining and Metallurgy," states that precision cutting with tolerances of a few thousandths of an inch in materials up to 2 in. thick can be attained with the present available equipment and a careful set-up, with proportional tolerances for greater thicknesses. The walls of the kerf can be made as smooth as tool-machine-cut work with precision cutting machines.

Oxy-acetylene cutting is a thermo-chemical process having its basis in the accelerated chemical reaction of oxygen with ferrous metals at high temperatures. The product of the cutting reaction in low-carbon steel is black or magnetic iron oxide, Fe_3O_4. In addition to the chemical reaction there is also a mechanical erosion by the oxygen stream, which causes some of the metal to be washed away in the metallic form. In practice, approximately three-fifths of the iron removed is in the oxide form (Fe_3O_4), the remainder being removed as molten iron. This mixture forms a molten slag which readily flows away from the cut surface.

From a theoretical standpoint, 1.305 cub. ft. of pure oxygen is required to oxidise 1 cub. in. of pure iron to black iron oxide, but in actual flame-cutting the amount of oxygen necessary to remove 1 cub. in. of iron from the kerf varies from 1.00 to 1.425 cub. ft. A small additional quantity of oxygen is required to unite with the acetylene in the preheating flames. The heat generated by the cutting operation is carried away by the oxides and melted metal or by the conductance of the adjacent metal. The rate of cutting, however, is such that new surface is continually brought up to the ignition temperature just ahead of the oxygen stream. The carbon and other alloying elements in the more common steels are present in such small quantities that their presence dissolved in the iron has but slight effect on the flame-cutting operation. Where the proportions of these elements are above normal, as in many of the newer steels, metallurgical considerations call for special cutting techniques to produce commercial results.

Low-Carbon Steel

In the normal oxy-acetylene cutting operation the effects of the heat of the cutting flame penetrate to a depth of only a few hundredths of an inch below the cut surface. The conduction of heat into the adjacent cold metal cools the red-hot metal along the sides of the kerf, producing, in ordinary steels containing less than 0.35 per cent. carbon, a sorbitic structure characterised by toughness. Flame-cutting therefore brings about changes in physical properties of the surfaces of such steels that are in no way detrimental to their serviceability, and are in fact usually more desirable than the properties of pearlitic surfaces.

Alloy and Higher-Carbon Steels

Changes in structure and properties of the alloy or higher-carbon steels, when they are subjected to the flame-cutting operation, may be quite different from that described for low-carbon steel. Troostite, or even martensite, may result from the cooling after cutting. Furthermore, expansion of the steel under the cutting flame is restrained by the adjoining cold metal, and "upsetting" of the heated metal is the result. When contraction from cooling takes place, severe stresses and sometimes incipient or visible cracks may develop if the usual procedures for cutting low-carbon steels are not suitably modified.

Consequently, metallurgical research sought a means of reducing the difference in the expansion between the metal along the kerf and the cooler adjacent metal, so that the more gradual cooling would bring about a reduction in the subsequent cooling stresses and prevent the formation of the undesirable martensitic or troostitic structures. Experience has shown that this desired condition may be brought about in these special steels if they are preheated before being cut. Temperatures as low as 500 to 600 deg. Fah. are beneficial, though higher temperatures are usually employed. The temperature conditions thus being more uniform, the tendency toward a stress-free condition is assured. Care must be taken, however, that the preheating temperature is kept as low as feasible (under 1,100 deg. as a rule), for then the control of the cutting oxygen jet is easier. The newer air-hardening low-alloy steels that have recently come into prominence come under these preheating recommendations.

In the heavier preheated sections a considerable temperature differential may exist between the metal at the surface and at the interior unless the preheating temperature is kept as low as practical and the cutting performed as quickly as possible after the metal has been withdrawn from the preheat. Otherwise the oxygen-pressure adjustment suitable for the lower surface temperature may not produce satisfactory results at the higher temperature within the section.

Under certain conditions it may be necessary to take special measures to preserve the alignment. This may be done in several ways, among which are clamping the part in position, cutting simultaneously or in rapid succession about the neutral axis of the part, or by skipping the cut at intervals, leaving a series of uncut sections along the line of cut which are later severed after the material has cooled as a whole.

Of primary importance in determining the economy and efficiency of the cutting operation are the factors of drag, speed, and oxygen pressure, and the inter-relationship existing among these. The oxygen jet in flame-cutting is usually perpendicular to the surface of the metal. After traversing about one-half the thickness of the cut, the cutting jet may curve backward opposite to the direction of travel. The amount of this lag is known as the drag of the cut, and is indicated by faint markings left on the cut face. This is more pronounced for heavier cuts.

Studies of the relationship of pressures, speeds, and drags show that for a given drag there is a constant relation between cutting oxygen consumption and cutting speed within a certain range having definite limits. Accordingly, it is possible to determine the proper drag, speed and pressure for greatest cutting efficiency for a given case. In straight-line severing operations, the question of drag is not of great importance; but in shape cutting, where curves and corners are involved, and where good square-cut surfaces are desirable, it is necessary to keep the drag as small as possible if the top and bottom contours are to be identical. This is particularly true with precision-machine flame-cuts.

Casting-Consciousness—II

(*Concluded from page* 171.)

The most cogent reason of all is, we think, the fact that between them there is no real competition in the sense that there is between castings and pressings or weldings or plastics, or between certain of the non-ferrous metals, because fundamentally they are made from the same raw material and hence economically their cost depends upon the degree of refinement and the amount of work put into them. Thus, while a certain measure of readjustment may occur between markets for grey and malleable iron, or between malleable iron and steel, or even between whiteheart and blackheart, they have far more in common than they have in competition, and hence can most advantageously be treated together. They will all stand to gain by their judicious development on proper lines. We shall conclude this examination next week, by considering the obstacles to such a development organisation.

More Details about the Düsseldorf Conference

The International Foundry Congress is divided into three sections:—(1) Congress meetings and Foundry Exhibition at Düsseldorf, September 16 to 20; (2) post-convention tour through Germany, September 21 to October 7; and (3) closing of congress in Berlin, September 25. The programme includes the following social items, the technical and other items being also briefly indicated to show continuity.

Wednesday, September 16

Morning.—The Registration Office will be opened at the Verkehrsverein, Ludwig Loewe Haus, near the Central Station (Hauptbahnhof), until Thursday morning; afterwards it will be located at the Exhibition Hall.

Afternoon.—Rhine trip to Duisburg *or* visits to foundries; also visit to Krupps (the latter is strictly limited and applications are subject to approval).

Evening.—Informal causerie at Alstadt-Brauerei Schlösser, Alte Stadt 5/13 (Schlösser brewery).

Thursday, September 17

11.30 a.m.—Opening of congress by the President of the State Bank, Dr. Schacht.

2 p.m.—Opening lunch on the Rheinterrasse (7 Rmk. wines included).

Afternoon.—Meetings of Verein Deutsche Giessereifachleute (limited to members).

5 p.m.—Tour of city, 2 Rmk. per person.

Evening.—Gala performances at Music Hall, Opera and Operetta Theatres at reduced rates.

Friday, September 18

9.15 a.m.—Technical Sessions (see our issue of July 23).

Afternoon.—Visits to foundries and works (1-6) (see our issue of August 20).

8.30 p.m.—"Rheinischer Abend," at invitation of Municipality at Zoo, Brehmstrasse entrance. With support of municipal ballet and premier artistic talent. Dancing. Illuminations. Illuminated fountains.

Saturday, September 19

9.15 a.m.—Technical Sessions (see our issue of July 23).

3 p.m.—Visit to Kaiser-Wilhelm Institut.

5 p.m.—At invitation of Düsseldorf Municipality: "Contemporary Music" in Benrath Rococo Castle (tram services 1 and 18).

Sunday, September 20

10 a.m.—Technical Sessions (see our issue of July 23).

1.30 p.m.—Closing (informal) luncheon on the Rheinterrasse.

LADIES' PROGRAMME

Wednesday, September 16

1 p.m.—Participation in Rhine trip to Duisburg.

Thursday, September 17

11.30 a.m.—Opening of exhibition.

5 p.m.—Tour of city.

Friday, September 18

9 a.m.—Motor-coach trip to Schloss Burg through Bergische Land. Leaving Kaiser-Wilhelm-Strasse, Hauptbahnhof (Central Station) at 3 o'clock. Fare 3.50 Rmk.

1 p.m.—Visit to "Persil" works. Departing as above; return 7 p.m. Fare 0.80 Rmk.

2 p.m.—Visit to the city of Cologne while members are at the Humboldt Works.

8.30 p.m.—Social evening at the Zoo (see main programme).

Saturday, September 19

10 a.m.—Trip by express train to Kaiserwerth, leaving Breidenbacher Station. Tour of town and visit Barbarossapfalz. Return by special Rhine steamer, about 1 p.m. Fare 1.50 Rmk.

5 p.m.—Reception at Schloss Benrath.

Members can participate in the visit to the Persil Works.

Some Considerations of Value to Foundrymen*

By F. ANDREW

One often hears moulding referred to as a highly skilled operation, and in order to acquire such skill it is essential that the would-be moulder should concentrate on each job which he has to make and to take note of his observations in order to build up an experience that will be useful to him in later years. There seems to be an idea that he has only to work with one or more journeymen moulders for a few years in order to become himself a skilled craftsman.

Each casting presents its own particular problem, whether it is a simple flat-back or even an open sand casting, and although there are and have been numerous examples of highly skilled craftsmen who have had little education other than that obtained during the making of moulds, there can be no doubt that the facilities now available for evening education are of great advantage in training the mind to make and retain useful observations. The period of apprenticeship is useful only if advantage is taken of it to learn the numerous pitfalls that lie in wait for the unwary. Book-learning may play an important part in training, but is useless unless supplemented by attentive study of the practical side of foundrywork.

Inquests

Inquests on bad castings carried out with an open mind can be very instructive, especially if approached with caution and a willingness to face facts, even though these point to defective workmanship on the part of the inquiree. Metal, sand, patterns, cores, moulding tackle, and other reasons are frequently blamed for what is too often faulty workmanship, and although this might appear to be the easiest solution in many cases, it does not tend to improve skill even if the individual is satisfied. One never ceases to learn; and the writer is quite willing to admit that he is constantly learning, and believes there are plenty of discoveries still to be made. Each fresh design provides new opportunities, and may be rightly called an experiment, carried out with the aid of knowledge gained from previous experiences. The accuracy of the observations and inferences taken and formed from previous work will determine the degree of success obtained in future results. How many moulders can with certainty cast, say, a flat plate 2 ft. square by 1 in. thick and guarantee a clean upper surface when machined? Watch an open sand plate poured and judge of the correct or incorrect preparation by the amount of bubbling that occurs during filling. These two examples may be considered very simple and are directly connected, but a careful study of them may make for success in a larger and more complicated casting.

Moulding and coremaking are not the only things to learn if an apprentice desires to become an efficient foundryman. An occasion may arise whereby a young foundryman may find himself in a district far removed from any other foundry and be expected to produce castings of a much higher class than firebars or sashweights. He may have to brick his own cupola, make his own cores and moulds, mix and melt his own metal, dress and even machine his own castings. Such opportunities—and they are real opportunities—do not occur often, but when they do it is well to be equipped with sufficient experience to meet the many problems that will arise when depending on one's self alone. Determination and self-reliance will be essential requirements and persistence will result in achievement and the pride which justifiably accompanies it.

Much advantage will be obtained if the individual concerned possesses at least a fair knowledge of the following:—Arithmetic or practical mathematics; general properties of matter; inorganic chemistry with, if possible, chemical analysis; mechanics; physics; metallurgy, and mechanical drawing. It would be foolish to expect that with these alone a man is fully equipped to become a successful foundryman, but they will be of considerable help in enabling him to overcome the many obstacles which beset the path of the practical foundryman. His progress will be more rapid and he will become more adaptable and versatile.

On the other hand, one sometimes finds a moulder quite capable and efficient in the making of a good type of casting, doing the same things every day without the ability or exact knowledge to say why he does these things, but nevertheless turning out a superior product. On another type of casting he may have indifferent results, due to inability to bring a trained mind to bear on any new difficulties that may arise.

Runners

Far too little consideration is generally given to runners or gates, and yet the location, type, shape, size and care taken in preparing them may each be determining factors in the successful production of castings.

Incorrect gates may cause, among other defects, cracks, leaky castings, blisters due to trapped air, buckles and scabs, faint runs and dirty castings. A large gate playing on one portion of the mould may result in an unsightly scab, the blame for this being laid to the facing sand. Had the metal been introduced at one or two additional points, the scab might have been avoided, and the probability is that the facing sand is standard and satisfactory for the whole or at least a section of the shop. A gate playing on a projecting portion of a mould for any length of time may not show any surface defect on the casting after dressing, but when machined a spongy area is liable to show up. This may be due to local superheating and formation of a hot-spot, or to excessive evolution of gases from that part on which the metal has been playing.

This evolution of gas may affect normal feeding of the casting at the point in question by cooling the metal sufficiently to prevent natural feeding. Gates should be placed in such a position as to cause the least possible turbulence, having a free entry into the mould. Wherever such agitation occurs, it will be found that the metal in the vicinity does not machine up "clean," the action being similar to that occurring in a Bessemer converter, resulting in a certain amount of oxidation, slag, and trapped gases. One cause of cracks, apart from an unyielding core, is inequality of cooling, and the application of gates on the lighter portions of castings in an endeavour to equalise the rate of cooling by thus superheating the lighter sections, will often prove successful. The same method will often obviate a crooked casting, and it is probably correct to say that equalisation of cooling, whether attained by disposition of runners, cooling the heavier sections by means of chills, or barring such heavy sections, will be more effective towards producing a casting reasonably free from stresses than the much practised method of providing a cambered pattern. Unfortunately, this equalisation of cooling is not always practicable, so the custom of cambering will continue unless facilities exist for casting in hot moulds and/or removal to annealing ovens so as to obtain slow and uniform cooling.

The sizes of runners can best be determined by experience, but, generally speaking, the writer prefers to use that size of runner which will fill the mould space in the shortest time consistent with the avoidance of turbulence, strain and trapped air. Down-gates, channels and ingates must be correctly proportioned to ensure that a continuous stream of metal is entering by each gate. Should the channels and gates be larger than the down gates, it is possible that air may be sucked from those portions of the channels not in contact with metal, resulting in a jet of air entering the mould space along with the metal, possibly causing oxidation and blowholes.

There are certain exceptions to this rule, as in cases where the metal is introduced into the mould vertically from underneath, and in such cases it is advantageous to have the connection between the mould joint and the bottom gates very much larger than the down gates which pass through the top box. In such cases development of air pressure in what may be termed this anti-chamber may cause air to be forced into the mould through the walls, causing blowing and consequent troubles. This may be prevented by the provision of an outlet similar to a riser from the top of this anti-chamber. Such a method will prevent the excessive fountain effect of this type of gate and give results not easily obtained by other means.

A point about circular down-runners not generally known to moulders is the relative capacity of different diameters. By doubling the diameter, the area is multiplied four times—that is, a 2 in. diameter runner has four times the capacity of a 1 in. diameter runner and only half the surface friction.

Excessive Moisture

The type of sand will have a great effect on the amount of moisture permissible. At all times excessive moisture should be avoided, as water, when converted to steam, occupies approximately 1,700 times its original volume. Damp sand does not pack so easily as dry sand and the extra ramming necessary increases the possibility of displacement of portions of the mould when the steam generated begins to escape.

It is not always possible to know that blowing has occurred in a mould by observation of risers or core-vents and if any doubts be entertained as to suitability of runners, density of ramming, moisture or permeability of sand, correct venting of cores, and pouring speed, a blank test can be carried out as follows:—

A mould is prepared in what is believed to be the correct manner, notes being taken of the particular treatment, and by providing a large aperture in the top box, observations of the following points will be possible:—(1) Behaviour of the metal entering the mould—steady or otherwise; (2) reaction of the bottom of the mould as it is being covered by the metal, and (3) the rate of filling of the mould, in this case using a mould with the core in position and noting any tendency to blow when the metal begins to cover the core.

It is commonly supposed that, because a core is dried, it may be rammed hard if vented and a few cinders put in the centre, but the above test will often show the fallibility of this theory. A common source of trouble with an otherwise perfect core is the lack of sufficient outlet for the escape of the gases.

At the temperature of molten iron, gases occupy about five times their volume at normal temperatures, and this expansion should be taken into account when providing outlets from cores or moulds, remembering particularly the relative areas of different diameters.

The reference to blank tests made previously is intended to refer to small moulds, and as the results may be taken to be indicative of what occurs in a large mould under relative conditions, they should prove valuable experience to an enthusiastic foundryman and enable him to visualise likely occurrences when making larger moulds. On small work one or two blank tests

* A Paper read before the Junior Section of the Lancashire Branch of the Institute of British Foundrymen.

made at the commencement of a large order may relieve the moulder and foreman of an accumulation of trouble at a later date by avoiding a pile of castings scrapped during machining because of defects.

Ramming and Venting

The advice "ram hard and vent well" is often given in a foundry, but unqualified acceptance of such advice is apt to cause much trouble. Venting is only an artificial aid to assist the sand and allow gases and air to escape from the face of the mould instead of entering the mould itself. It is possible to ram some varieties of sand so hard, and without great effort, that no amount of venting will effect this result. The sand face may be so closely packed as to admit of no expansion, when heated by contact with the metal, except into the mould space, producing the defects known as shell scabs or buckles. These leave unsightly hollows in the face of a casting when removed. The blowing which generally occurs at such places may cause portions of such sand to become entirely free and float on the metal to the upper parts of the casting, forming sand holes and leaving behind a patch of solid scab to be chipped off.

The closer the sand the more prevalent this trouble. An experienced moulder realises this, and also knows the difference between "hardness" and "firmness," using the vent wire to provide channels for the collection of gases escaping through the pores of the sand in those areas not pierced by the wire. Hand ramming makes the sand grains lie closer together, and thus reduces the permeability of the sand, so that the vent channels need to be closer together to assist easy escape of the gases. With coarser sand, the spaces between the grains are greater, and fewer channels will be necessary than with the closer or finer sand, even though both are rammed equally hard. To ram unnecessarily hard, and thus render extra venting necessary, is to waste both time and energy. It is frequently found that small wooden patterns are so disfigured by vent wire marks as to make impossible the production of presentable castings from them. This is due to lack of knowledge on the moulder's part of the possibilities of his sand if properly treated. With small castings, and many others where the depth is not great, ramming with a peg rammer (which often gets too near the pattern) may be dispensed with except round the sides, and in the final stages in some cases, the sand being either pressed with the hand, shovel handle or trodden, being finished off with a flat rammer on plenty of sand.

By this means a mould can be made practically self-venting, for after scraping off the excess sand, the mould is uniformly firm and open, without the irregular character and dead pockets produced by the small-ended peg rammer. Many of the defects found in castings only when machining commences may be attributed to defective ramming. Although the mould may have been well vented and the gases appeared to escaped freely, blowing may have occurred during casting, without any outward indication at runner or risers, due to their position, and the resultant casting may be thought perfect until machined.

A common error in the case of the sides of deep moulds, especially when the casting is a heavy one and takes relatively a long time to pour, is the provision of continuous vents close to the mould face. These allow large quantities of steam to pass, which, being cooled and condensed by the relatively cold upper end of the vents, saturates the adjacent face of the mould long before the metal reaches it, resulting in boiling and scabbing, when eventually the mould is filled. The better way is to have two, three, or more series of vents at different levels, where they are collected by channels filled with dry coke leading away to the outside of the pit to vent pegs common to all levels, thus leading the gases and steam away from the mould face at casting time.

A Wall-Box Casting

The reactions which occur may be appreciated by considering a large wall-box, with internal webs top and bottom. If vents be made vertically and continuous from one web to the other, the face of the upper web is almost certain to blow and scab. The slower such a mould is filled, the greater the probability of such steaming, which, with the best of conditions, is always present and accounts partially for the increasing tendency to dry or skin-dry moulds of large size. The rate of pouring may be increased or reduced by respectively hot or dull metal, and often accounts for the apparent anomaly of less scabbing with hot metal than with dull metal, the dull metal allowing greater opportunity for the effects of the steam and being also less able to recover from contact with damp portions of the mould.

In the case of dry-sand moulds removed to a stove for complete drying, as distinct from skin-drying, much laborious venting may be dispensed with, except in the case of complicated moulds.

If the whole of the mould be rammed up in a strong, close sand, or stoving conditions are bad, extra venting may become necessary, to allow for quicker drying by providing outlets for steam. Unless boxes have to stand severe handling, the practice of coating the outside of a mould with clay wash may be discontinued with advantage, as providing a serious obstacle to the escape of gases and creating greater need for vents. Although it is often stated that extra vents are never lost, the effect on some patterns is deplorable, and, apart from the extra labour and time for venting, extra finishing is also entailed. Except in cases where a mould is completely rammed up in a pit after drying, there are very few cases of dry-sand moulds where venting could not be virtually eliminated, provided that after a facing of core sand next to the pattern the remainder of the mould consisted of ordinary floor sand rather damper than is used for green sand work, such sand drying quite firm and allowing gases to escape freely. In the case of moulds buried entirely in the floor after drying, the necessary vents should be collected by means of a layer of coke inside the moulding box, and led to an outlet above the floor, or if vents come to the outside of mould, use may be made of straw laid up the side of the box while ramming up the pit.

Publication Received

Aluminium Production Properties and Applications. Published by the British Aluminium Company, Limited, Adelaide House, King William Street, London, E.C.4. Second edition.

A perusal of this brochure gives the impression that at least a partial solution has been found to the problem of how to learn metallurgy with a minimum of mental exertion. The story of the conversion of bauxite into pure aluminium and the working up of the metal into articles of commerce is told in such easily readable language that one is apt to forget that all the essential facts and figures are being disclosed. Moreover, the text is so delightfully illustrated, that it quite throws a glamour over what experts know is just a series of everyday metallurgical processes. To have compressed this work to about fifty pages and yet to have omitted nothing of material importance is an indication of the thorough manner in which the task has been tackled. It is free from tabulated data—a matter splendidly dealt with in other publications issued by this company and this helps to free the book from any drabness. We are reasonably sure that requests from our readers for this brochure will be courteously entertained by the issuing house.

Random Shots

The dirty work has begun! A challenge has been thrown to the Institute of British Foundrymen by the Works Managers' Association (Birmingham Branch) to meet them in mortal combat at cricket on the grounds of the Midland Car Club, King's Bromley, near Lichfield, on Sunday afternoon, September 13, at 2.30. The challenge has been accepted, and the FOUNDRY TRADE JOURNAL has been fortunate in securing Mr. K. B. E. Frizzle, the well-known international darts champion, to comment, in his own inimitable manner, on the highlights of the game.

* * *

Already "Marksman" is realising that his readers are wondering about the dirty work—cricket isn't dirty work—if you eliminate bodyline bowling. Yet this match, as is the case with all big events, is swayed by strategy, politics, wire-pulling, startling headlines and all the rest of the blah-blah. Here is the stone-cold truth: the W.M.'s (not Worshipful Masters) have already poached two players of outstanding worth—Jack Gardom, fast bowler and Jessop-like slogger; and W. Todd, the well-known stone-waller and spin bowler; both of these willow-wielders are members of the Institute and their residential qualification for the W.M.'s is definitely suspect. Lennox Holt, the Institute's fast bowler, is so incensed over this poaching business that he has the firm promise of his captain, Jimmy Hurst, that he takes over the bowling from windward immediately Jack comes in to bat.

* * *

If any other member of the Institute feels equally strong resentment and would like to vent his feeling from leeward, it may still be possible to include him in the team. "Marksman" half fancies a good stumper would be welcome.

* * *

At long last the programme for the Düsseldorf Congress has been completed. Beer evenings—"Marksman" will get in as much practice as possible whilst watching the cricket match at Lichfield—luncheons, high jinks at the Zoo and various trips up and down the Rhine are all included on the social side. As there are no official banquets until the caravanserai reaches Berlin, the lads and lassies can spend their evenings listening to Bach's fugues and canons, or if they prefer it trip the light fantastic measure at the Young Miller, the Crystal Palace, or the Red Carpet—if such temples of merriment still exist under Germany's new management.

* * *

The American delegation is said to be so small that they can undertake their pre- and post-convention tours in a taxi cab. However, if they feel lonely, the Britische Mitglieder will adopt them, providing (1) they will stand drinks round or, alternatively, tease any Scottish delegates present to act on their behalf, (2) retail the latest Mae West stories, and (3) refrain from using Christian names before the fourth round.

* * *

Mr. Richard Miles has not written "Marksman" intimating whether or not he is making the trip, but if he were it would be interesting for him to get up a sweepstake as to the relative size of the various delegations. In case somebody would like the job, here is the betting forecast in order of size:—Austrians; Czecho-Slovaks; British; Belgians; Poles; French; Italians; Americans; Russians; Dutch; Swedes; Norwegians; Swiss; Danes; and poor old Spain (0). In making the forecast one has to take into consideration politics, finance, distance, trade conditions, travel—prizes for good moulders—foreign branches of German technical activities.

MARKSMAN.

The Impact Testing of Cast Iron

By J. W. DONALDSON, D.Sc.

The capacity of a material to resist shock is in many cases of secondary importance, but in other cases, where structures are required to withstand sudden application of load, or are subjected to vibratory stresses, a high impact-resistance is necessary. In the mechanical testing of materials and particularly of steels, impact tests have therefore been recognised for many years as being of primary importance, and are now regularly included in specifications of materials, which have to withstand shock and vibration. Cast iron is not used commonly to resist impact or shock, but the development of high-duty and alloy cast irons and their application during recent years to parts subjected to such conditions, and the knowledge that in different cast irons there are varying degrees of brittleness not revealed by direct tensile and transverse tests, have led to a number of investigations to determine what impact resistance various types of cast iron possess.

In order to determine the inherent capacity of materials to resist impact or shock, many forms of testing have been devised. These are either single blow tests or repeated blow tests. Among the accepted forms of the former in common use are the Izod, Charpy, Guillery, and Frémont tests, and of the latter the Stanton test. In these methods of testing, standard sized specimens provided with a notch or notches of given dimensions are subjected to impact forces applied by means of either a pendulum, flywheel, or falling weight in a machine capable of recording the energy absorbed during the fracture of the specimen across a notch. The most widely used machines are the Izod and Charpy, both of which are of the pendulum type. The former is the machine generally used in this country, and the latter the machine used on the Continent, while in the United States both types are in use.

Object of Notching

The object of notching the specimen or test bar in impact testing is to localise the fracture and to concentrate the stress at the smallest area of the material. By doing so, the material breaks through this area without deformation spreading to the adjacent portion, and the energy absorbed is principally the energy required to break the specimen, any energy required for deformation—energy which varies with different metals and alloys—being practically eliminated. The advantage of notching, however, is only obtained with ductile materials such as steel, which show appreciable deformation on fracturing, and is of little value in brittle materials like cast iron, which break with little deformation. The result is that in most impact tests, which have been carried out on cast iron, the notch is eliminated and tests are carried out on un-notched bars.

Types of Tests Used

Various forms of impact tests have been applied to cast iron during the last 30 years, but it is only within comparatively recent years that there has been any attempt to standardise such tests, and to make a series of systematic investigations on the impact properties of various cast irons, and to correlate, if possible, the impact resistance of cast iron with other properties. An early investigation on the impact strength of cast iron is found in the experiments of Keep[1], who determined the impact resistance of cast irons with varying percentages of silicon and manganese. Such experiments were carried out on square test bars supported at each end and broken in the centre by means of a single blow from a pendulum hammer. The impact strength of cast iron was also determined by Cook who subjected a test bar to a number of blows from a weight falling from a gradually increasing height until the test bar fractured, when the final height of the weight was taken as a measure of the impact resistance of the material. Impact tests, using a 120 ft.-lb. Izod machine and an un-notched 20 mm. by 20 mm. by 75 mm. test bar were made by Rowe[2] on cast irons containing 0.36 to 1.29 per cent. phosphorus, when values decreasing from 29 to 10.5 ft.-lbs. were obtained.

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3 H. F. Moore and S. W. Lyon, Proc. Amer. Soc. Testing Materials, 1927, Vol. 27, Part 2, p. 87.
4 J. B. Kommers, Proc. Amer. Soc. Testing Materials, 1928, Vol. 28, Part 2, p. 174.
5 Report of Sub-Committee XV of Committee A-3 on Cast Iron, Proc. Amer. Soc. Testing Materials, 1933, Vol. 33, Part 1, p. 87.
6 F. B. Dahle, "Metals and Alloys," 1934, Vol. 5, p. 1.
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In France impact tests on cast iron were at one time commonly specified in conjunction with tensile tests. These were made out by dropping a weight of 12 kgms. on to a test specimen 40 mm. by 40 mm. by 200 mm. long resting on supports 160 mm. apart. This test was included in a number of specifications, but the initial height of the weight and the increase in height after each blow varied in different specifications. A Charpy form of impact test was also made on test specimens 10 mm. sq. on supports 50 mm. apart. The results obtained from these tests, however, did not correlate well with other tests, with the result that such tests have been replaced to a large extent by transverse and shear tests.

Single-Blow Machines

Modern forms of single-blow impact tests for cast iron are usually carried out on modified forms of the Izod or Charpy machine or by using modified forms of test pieces. The machines are usually of lighter construction when compared with the standard machines, and the test pieces vary considerably from the standard Izod or Charpy test pieces and are usually un-notched. The types of machines and specimens which have been used in systematic tests will be considered when dealing with such tests.

In carrying out single-blow impact tests on cast iron, a fracture is produced somewhat similar in nature to the fracture produced in tensile or transverse tests, being intercrystalline in character. This is different from what occurs when ductile materials, such as steel, are tested, where the mechanism of failure in impact has been shown to be of a distinctly different nature from that which occurs in tension. The results obtained in cast iron impact-testing bear, therefore, a certain relation to those obtained for the deflection in the transverse test, and it has been suggested that comparable results might be obtained by plotting the deflections obtained for increasing loads in transverse up to the point of final rupture, with the result obtained by fracturing an un-notched bar by means of a single blow.

Correlation Difficulties

When cast iron is subjected to a series of repeated blows, the interpretation of the impact value obtained becomes more complex and more difficult to correlate with other tests. The Stanton test, which is the impact test generally used for steels, consists in dropping a hammer or tup of known weight from a given height on to a standard notched test piece, which is rotated through a given angle between each blow. The number of blows required to fracture is taken as the impact value. If a heavy hammer be used, the number of blows to produce fracture is comparatively few, and the test bears a relation to the single blow test, whereas, if the hammer be light, the fracture is produced by a large number of blows, and the test bears a relation to the fatigue test. The mechanism of the repeated blow test is also different from the mechanism of the single blow test, as fracture results from crack propagation and takes place without deformation.

A modified form of the Stanton test has been adopted by the British Cast Iron Research Association as an impact test for cast iron. In this test a 4.8-lb. tup or hammer operated by means of a cam is dropped from a height of 1.2 in. on to a test specimen of approximately ¾ in. in dia. with a groove in the centre. The test bar is fitted into a machine horizontally and rotated, being shaped at each end so that it may be held properly and its rotation controlled. The average number of blows approximates to 90 per min. and the test bar is rotated through an angle of 180 deg. between each blow; and the number of blows required to break the bar is recorded automatically. The impact strength of cast iron is taken as the number of blows required to produce fracture.

This test is essentially an empirical one, and no attempt has been made to correlate the re-

TABLE I.—*Composition of Cast Irons (A.S.T.M. Tests).*

Test mark.	T.C.	Gr.C.	Si.	Mn.	S.	P.	Ni.	Cr.	Other elements.
A	3.49	2.72	1.68	0.54	0.074	0.74	—	0.01	—
B	3.53	2.69	1.67	0.56	0.076	0.68	—	—	—
C	3.95	3.09	1.90	0.65	0.060	0.07	0.01	—	—
D	3.25	2.66	2.08	0.53	0.050	1.99	0.03	—	0.16 Ti
E	3.12	2.44	2.18	0.44	0.096	0.63	—	—	—
F	3.61	2.93	2.06	0.52	0.062	0.75	—	—	—
G	3.49	2.78	2.08	0.55	0.078	0.19	1.17	0.65	—
H	3.39	2.75	2.50	0.74	0.062	0.43	0.01	—	0.16 Ti
I	3.41	2.85	2.44	0.57	0.070	0.63	0.01	0.02	0.10 Ti
J	2.61	1.73	2.38	0.77	0.105	0.06	1.08	0.09	—
K	3.14	2.30	2.69	0.82	0.094	0.18	0.25	0.09	—
L	3.05	2.20	2.70	0.79	0.089	0.16	0.60	0.24	0.45 Mo
M	3.46	2.82	2.35	0.69	0.092	0.15	0.65	0.02	—
N	2.53	2.03	3.26	1.01	0.035	0.02	10.59	1.55	4.07 Cu
O	3.43	2.75	2.35	0.73	0.092	0.20	0.01	0.01	—
Q	2.88	2.25	1.99	0.51	0.098	0.43	0.01	0.01	—
R	3.24	2.41	1.63	0.56	0.084	0.42	0.06	0.01	—
S	3.38	2.59	1.18	0.82	0.078	0.14	0.95	0.01	—
T	3.49	2.16	0.53	0.42	0.133	0.33	—	0.01	—
U	3.52	2.68	2.94	0.66	0.042	0.04	0.01	0.01	0.34 Cu
V	2.50	1.50	2.20	0.74	0.088	0.04	—	0.08	0.12 Cu
W	3.79	2.99	1.47	0.73	0.083	0.12	0.01	0.01	0.21 Cu
X	3.08	2.32	2.07	1.21	0.047	0.04	16.29	1.89	6.12 Cu
Y	3.07	2.22	1.97	0.63	0.072	0.40	0.01	—	0.12 Cu
Z	2.79	1.94	2.44	0.50	0.060	0.03	0.50	0.09	0.36 Cu

sults obtained with it with other test results, or to include it in any specification for cast iron. It is used by the Research Association as a laboratory test to determine the relative toughness or resistance to shock of various cast irons, and as a more sensitive means of distinguishing the quality of cast irons than tensile or transverse tests. It is also considered as giving more definite information than a single blow test and at the same time not being so involved as a long duration fatigue test, and the results obtained from it are regarded as satisfactory when considered within those limits.

TABLE II.—*Average Impact Tests (A.S.T.M. Tests).*

Test mark.	Pendulum tests 1.2-in. dia. bar. Ft.-lbs.			Drop test, 1.2-in. dia. bar. Average drop, in.				Izod test. Ft.-lbs.		Charpy test. Ft.-lbs.		Krupp-Stanton repeated blow.	Direct tension, 0.5-in. dia. bar. Ft.-lbs.
				No. 1.	No. 2.	No. 3.	No. 4.						
	Charpy, 18-in. span.	Russell, 18-in. span.	Russell, 8-in. span.	25-lbs. hammer. 6-in. span. 2-in. first drop. ½-in. increment.	11-lbs. hammer. 5-in. span. 1-in. first drop. 1-in. increment.	25-lbs. hammer. 6-in. span. 1-in. first drop. 1-in. increment.	25-lbs. hammer. 6-in. span. 2-in. first drop. 2-in. increment.	Small specimen un-notched.	Small specimen notched.	Small specimen notched.	Small specimen un-notched.		
A	47.3	551	351	10.5	20.0	17.3	11.5	3.68	0.9	0.83	2.9	3,424	7.2
B	54.7	496	345	9.2	20.0	16.7	12.0	3.96	0.8	0.83	2.6	3,703	7.5
C	42.4	473	299	7.0	15.3	12.0	8.0	4.14	0.8	1.00	3.3	2,241	6.2
D	17.6	151	151	4.3	11.0	6.7	4.7	2.17	1.0	0.42	2.1	1,116	4.4
E	60.9	641	416	11.2	22.0	20.3	14.0	4.15	1.4	0.83	2.5	3,312	8.6
F	38.5	430	278	7.5	15.7	11.7	8.0	3.60	1.0	0.75	2.6	1,029	6.1
G	56.6	587	383	10.8	23.0	17.7	13.5	4.16	1.5	3.00	2.9	4,647	6.8
H	41.1	461	339	9.2	19.0	14.0	11.0	3.28	1.3	0.67	2.6	3,145	9.2
I	40.3	427	290	7.0	16.0	11.7	8.0	3.39	1.0	0.75	2.7	503	5.3
J	67.0	966	511	15.2	31.0	23.3	18.0	5.69	1.5	1.00	3.0	8,921	11.7
K	57.6	641	401	10.2	24.7	15.3	13.5	3.86	1.1	0.83	2.6	1,849	7.5
L	67.4	806	487	13.5	31.3	22.3	16.0	5.06	1.6	0.83	3.1	2,923	11.5
M	61.7	681	421	9.8	21.3	16.3	12.0	5.44	1.3	1.00	3.3	530	8.5
N	139.8	1,907	922	13.5	30.7	16.7	18.0	10.00	2.3	2.75	5.0	6,547	12.3
O	61.1	615	433	9.5	21.0	14.7	12.0	4.91	1.3	1.00	2.8	515	8.3
Q	84.2	963	582	13.8	29.3	24.0	15.0	6.18	1.7	3.00	4.1	3,912	11.7
R	63.3	707	512	12.2	27.0	18.7	14.0	4.37	1.4	0.92	3.1	1,925	13.3
S	61.7	602	440	10.8	25.0	18.0	11.5	5.15	1.6	1.00	3.2	5,347	8.9
T	50.7	586	478	12.6	28.3	13.0	16.0	—	—	—	—	—	—
U	42.4	501	339	7.8	17.3	13.7	10.0	3.65	1.1	0.75	2.6	1,331	5.6
V	55.1	580	391	13.2	30.3	20.3	13.0	4.42	1.8	0.92	2.7	6,461	12.0
W	51.2	510	376	8.2	18.0	12.7	9.0	4.19	1.1	0.83	2.8	478	6.0
X	128.7	1,120	1,054	12.3	28.0	24.0	16.0	9.50	1.9	7+	3.6	—	7.7
Y	56.8	563	358	12.0	23.0	18.3	12.0	3.86	1.3	0.67	2.3	5,216	7.5
Z	138.8	1,632	935	21.4	47.0	28.0	24.0	8.16	1.7	3.0	4.1	19,235	19.7

American Research

There are little published data available of systematic investigations on the impact testing and impact resistance of cast iron. The number of investigations which have been carried out to determine either the relation between the impact properties of cast iron and other properties, or to determine the usefulness of the several forms of impact test as applied to cast iron, or to determine the impact resistance of various plain and alloyed cast irons, has been few. Such investigations as have been undertaken have been carried out during comparatively recent years, and have been the work of American investigators.

The early work of Keep[1], who determined the impact strength of cast iron with varying proportions of silicon and manganese, has already been referred to. The results obtained, however, give little definite information regarding the influence of either element on the impact resistance. Moore and Lyon[3] in their experiments on the fatigue strength of four cast irons include impact tests together with other physical data. These tests were made on a small Charpy test piece 0.394 in. square by 2 in. long with a keyhole notch, and vary from 1.5 to 11.8 ft.-lbs. No attempt is made to correlate these results with other test results. Kommers[4], investigating the static and fatigue properties of cast iron, tested a series of ten cast irons and included impact tests. The impact tests are made on a Russell impact machine, using a 12-in. span. This machine consists essentially of a slab of steel weighing 185 lbs., which rotates, as a pendulum, about an axis 33.5 in. distant from the striking edge. The results obtained show little relation between the impact value and other static properties, and when compared with the endurance limit or fatigue value give a ratio varying from 500 to 900 with an average of 682 and a mean variation of 17.3 per cent.

A.S.T.M. Investigations

A systematic series of tests to determine the utility of the various forms of impact tests, as applied to cast iron, was made by Committee A-3 on Cast Iron of the American Society for Testing Materials.[5] The investigations covered twenty-five cast irons and included a wide range of compositions and melting methods. The compositions of the various irons are given in Table I. The irons were cast in green sand with two exceptions, and melted in various types of furnaces, including cupola, air furnace, electric furnace, and rotary furnace. The test bars were 1.4 in. in dia., 21 in. long irrespective of the suitability of the iron for this section, and all analytical results have to be considered in the light of the section cast, and the absolute values obtained are considered of less importance than the relation between the static and impact tests.

The test data on the various irons include, besides chemical composition, complete transverse tests (Standard B.S.I. test and a Standard French test), tension, compression, endurance, shear, and Brinell and Rockwell hardness tests. Thirteen sets of impact tests were taken. These include Charpy tests on 1.2 in. dia. bars at 18-in. span; Russell tests on 1.2 in. dia. bars at 18- and 8-in. span; four drop tests on 1.2 in. dia. bars; Izod and Charpy tests on small specimens both notched and un-notched; a repeated blow Stanton test, and a tensile impact test. The drop tests were carried out with varying weights of hammer, span, height of initial fall, and subsequent increments as will be seen in Table II, which gives the various impact test results. The un-notched Izod tests were made with a 10 ft.-lb. machine on a rectangular test bar, 0.5 by 0.75 in. and 3.25 in. long, and the notched Izod tests with a 20 ft.-lb. machine on a test specimen, 0.409 in. by 0.315 in. and $2\frac{1}{32}$ in. long, having a $\frac{1}{32}$ in. square notch. The un-notched Charpy tests were made with a 21.3 or a 15.1 ft.-lb. machine on a specimen, 0.394 in. sq. by 2.1 in. long, and the notched Charpy tests on an Amsler machine of 240 ft.-lbs. capacity with a test bar 0.394 in. sq. by 2.0 in. long, having a 45 deg. notch 0.079 in. deep and 0.01 in. radius. The repeated-blow tests were made by the British Cast Iron Research Association, using a specimen 15 mm. dia. with a 5 mm. groove, 1 mm. deep. The distance between the supports was 100 mm. and the specimen was rotated 180 degs. after each blow. A 4.81-lb. hammer with a drop of 1.2 in. was used, and 84 blows per min. were struck. Tensile impact tests were made with a Charpy impact machine of 224 ft.-lb. capacity, using a specimen 0.5 in. dia., having a 2.25 in. radius.

With the results obtained and from the resilience, modulus of rupture, and modulus of elasticity calculated from the transverse test results, an endeavour was made to correlate the impact strength with the various static tests. A comparison between the several forms of pendulum impact tests and the resilience gave curves which are good except for cast iron N, a martensitic iron, and cast iron X; an austenitic iron, where the 8-in. span gave a value far above the 18-in. span. The results of the tensile impact tests plotted against the product of the transverse resilience and the tensile strength, and of the repeated impact tests plotted against the transverse resilience, showed a definite lack of relationship in both cases. The falling hammer impact tests, however, plotted against the product of the transverse resilience and modulus of rupture and against the resilience remaining after repeated stressing just below the breaking point showed a more definite relationship.

The Charpy and Izod tests on notched and un-notched bars gave results of questionable value, and are not recommended for the impact testing of cast iron. Tests made on the larger un-notched test bars in both Charpy and Russell testing machines gave much better results. It was also concluded that the bending curve of the transverse test, if the test is accurately carried out, is capable of giving most of the information required about cast iron, and the Brinell hardness determined over the whole cross-section is the most valuable supplementary test. Drop test machines differ greatly in their construction, but would probably become more generally used if the machines were carefully standardised in all dimensions, and tests would then give valuable corroboration to the results of the transverse test. The Committee did not recommend that impact test requirements should be included in specifications.

TABLE III.—*Composition and Properties of Irons (Dahle).*

No.	Composition.							
	T.C.	C.C.	Gr.C.	Si.	Mn.	S.	P.	Mo
108	2.81	0.70	2.11	1.69	0.86	0.028	0.073	—
99	2.63	0.96	1.67	1.75	0.63	0.090	0.051	0.82

Tests at Room Temperature.

No.	Tensile strength. Tons per sq. in.	Transverse strength 1.25-in. bars, 12-in. span.	Brinell hardness.	Tensile impact. Ft.-lbs.	Charpy un-notched impact 0.505-in. bars. Ft.-lbs.
108	19.0	4,000 lbs.	234	14.2	3.75
99	23.2	6,100 lbs.	270	18.2	4.50

Elevated Temperature Tests

The impact resistance of ordinary grey cast iron and of molybdenum cast iron at elevated temperatures formed the subject of an investigation by Dahle[6], and resulted from failure due to sudden shock in tension when studying the

creep properties of molybdenum cast iron. Tensile impact tests were therefore made on this cast iron and on a plain cast iron over the range of temperature from 370 deg. to 538 deg. C., and for comparison purposes Charpy impact tests on round un-notched bars were also made over the same range of temperature. The composition of these irons and the tests at ordinary temperature are given in Table III.

The tensile impact tests at elevated temperatures were made by means of a special adaptation of an Amsler impact machine and an electric furnace supported by the steel arms leading from the anvil to the back cross-bar. The front adapter attached to the specimen was designed to engage the tup of the Izod hammer at the bottom of the swing and the back adapter was bolted to the cross-bar, which resists the impact blow. The front adapter was calibrated to determine the energy required in overcoming its inertia, and the average value obtained in the calibration was deducted from the energy obtained in a test to determine the energy consumed in breaking the specimen.

The high-temperature tensile impact tests were made on specimens 5 in. long machined with a short reduction section having a radius of $\frac{3}{8}$ in. and a diameter of 0.505 in., this diameter being chosen after previous tests had indicated that smaller sections did not give results sufficiently large to be discriminative. The Charpy impact tests (un-notched) at elevated temperatures were also made on round sections, 0.505 in. diameter, so as to have the same section in the two tests. The results obtained are given in Table IV, and show the general tendency of the tensile impact tests to follow the values obtained in the better-known Charpy tests.

TABLE IV.—*Impact Test (Dahle).*

No.	Foot-pounds energy.									
	Room temperature.		Temperature of test—Deg. C.							
			371		427		482		538	
	Charpy un-notched.	Tensile impact.	Charpy un-notched.	Tensile impact.	Charpy un-notched.	Tensile impact.	Charpy un-notched.	Tensile impact.	Charpy un-notched.	Tensile impact.
108	3.6	13.8	3.2	9.7	3.6	10.3	3.3	10.9	2.6	9.8
	3.9	14.6	3.4	10.3	3.5	10.4	3.2	10.3	3.0	11.4
Aver.	3.7	14.2	3.3	10.0	3.5	10.3	3.2	10.6	2.8	10.6
99	5.0	17.6	5.0	14.7	4.6	13.9	3.0	12.9	2.8	12.3
	4.1	18.8	5.4	14.4	5.5	14.0	4.8	12.8	3.2	11.3
Aver.	4.5	18.2	5.2	14.5	5.0	13.9	3.9	12.8	3.0	11.8

Superiority of Molybdenum Iron

These results showed the molybdenum cast iron to have a superiority in impact resistance over the ordinary grey cast iron, and that it retained its superiority in the various tests made up to 427 deg. C., and then dropped off at the higher temperatures. The results were also compared with the Charpy un-notched tests and the tensile impact tests on cast irons Q and L tested by the A.S.T.M. Sub-Committee (Table I). The ordinary grey cast irons, whose compositions are somewhat similar, show good agreement in the impact tests, and the molybdenum cast irons, whose compositions differ considerably, have relative impact strength, which are in line with the relative compositions and tensile strengths of the two cast irons.

A recent investigation on the impact strength of cast iron was made by Phillips' who determined the impact resistance and other physical properties of alloy grey cast irons. Samples from 38 cupola heats and 20 electric furnace heats were tested, and the alloy additions were chromium, molybdenum, nickel, copper and titanium. In addition to impact tests, tensile, standard A.S.T.M. transverse, Brinell and Rockwell hardness tests were also made. Repeated blow impact tests were made on un-machined halves of 1.2 in. diameter transverse bars, resting on supports 6 in. apart by dropping a 25-lb. hammer from a height of 1 in. and then increasing the height by 1 in. after each succeeding drop till the bar fractured. Single blow impact tests were made on a Charpy machine on halves of the transverse test bars, ground to 1.125 in. diameter, resting on supports 6 in. apart in a machine of 125 ft.-lbs. capacity. Less than a third of the iron was subjected to the single blow test, and ten of the electric furnace irons were heat-treated before testing.

Influence of Alloy Additions

The influence of alloy additions on the impact resistance and other properties shows considerable variation with the different elements added. Increasing nickel from 0.38 to 1.8 per cent. produced little change in hardness, tensile strength, and impact resistance, but resulted in an increase in transverse strength and resilience. Chromium in proportions from 0.23 to 1.37 per cent. increased the hardness in proportion to the increased chromium content. The tensile strength and repeated drop impact increased to 0.72 per cent. chromium, when the impact decreased with further increase in chromium, while the tensile strength was about equal to that of the base metal. Transverse resilience followed the same trend as the repeated drop impact. An increase in molybdenum from 0.3 to 0.8 per cent. increased the hardness, tensile strength, transverse strength and resilience.

The impact resistance of the base iron was unusually high, and the higher molybdenum irons, therefore, showed lower impact values, but it was considered that under normal conditions the impact values would increase with increasing molybdenum content. The nickel-chromium irons tested contained 0.45 to 2.07 per cent. nickel and 0.23 to 0.92 per cent. chromium, and showed an increase in transverse strength, transverse resilience, and impact values up to 1.2 per cent. nickel and 0.53 per cent. chromium, but a decrease was noted with higher nickel and chromium contents. In the case of the nickel-molybdenum irons, increasing the nickel from 0.4 to 1.01 per cent. and adding 0.6 per cent. of molybdenum raised the impact (repeated drop) from 21.9 to 38.5 ft.-lbs., while with further increase of nickel to 1.95 per cent. and molybdenum to 0.9 per cent., the value increased to 39.6 ft.-lbs. In the single blow tests values of 44.5 and 76.0 ft.-lbs. obtained. An addition of 0.6 per cent. of titanium or 0.6 per cent. of titanium and 1.3 per cent. of copper produced a slight increase in transverse strength, transverse resilience, tensile strength, and impact resistance. Increasing phosphorus from 0.16 to 1.48 per cent. produced a decrease in the impact resistance from 26 to 12.4 ft.-lbs. in the repeated drop tests.

The transverse resilience of cupola alloy irons showed a fairly good relation to the impact resistance, as measured both by the repeated drop tests on unmachined bars, and by single blow tests on machined bars. The single blow tests on machined bars appeared to be more sensitive and more nearly in agreement with the transverse resilience. In the case of the electric furnace irons, which were cast grey, an austenitic iron showed the highest impact resistance, while the same iron with the chromium increased from 2.12 to 3.81 per cent. showed about half the impact resistance. Izod tests were carried out on ten cupola and four electric furnace irons on a machine of 120 ft.-lb. capacity. The bars were tested in the unmachined condition, and were broken 3 in. above the supports in a cantilever type of break. In Table V are given the results obtained for transverse resilience, repeated drop impact, Charpy type single blow impacts, and Izod type single blow impact for these fourteen cast irons.

Correlation of Results

Generally speaking, the results for all the tests indicated that in the case of irons cast grey, and omitting austenitic iron, fairly high carbon nickel-molybdenum irons, which contain some chromium had good impact resistance properties. The highest impact resistance was obtained with irons which were cast white and converted to grey irons by annealing. Austenitic irons of low hardness had high impact resistance, and apart from the austenitic irons it appeared that low carbon irons were less shock resistant than those of medium carbon content,

(*Concluded on page* 178.)

TABLE V.—*Composition, Transverse Resilience, and Impact Tests on Cupola and Electric Furnace. Alloy Cast Irons (Phillips).*

No.	Composition.						Transverse resilience. In.-lbs.	Repeated drop impact. In.	Charpy single blow impact. Ft.-lbs.	Izod single blow impact. Ft.-lbs.
	T.C.	Si.	Mn.	Ni.	Cr.	Mo.				
1	3.63	2.29	0.57	—	—	—	363	8.0	25.0	22.0
2	3.53	2.25	0.59	0.71	0.25	—	410	10.0	33.0	33.0
3	3.49	2.03	0.58	0.51	0.24	—	489	12.5	37.0	41.0
4	3.49	1.95	0.61	0.70	0.25	—	444	12.5	31.5	37.0
5	3.38	2.23	0.60	1.46	0.15	—	533	11.5	34.0	35.0
8	3.36	2.01	0.62	1.10	0.66	—	454	12.0	33.0	40.0
9	3.44	2.12	0.60	1.01	0.24	0.60	626	18.5	44.5	38.0
10	3.41	2.11	0.60	1.95	0.21	0.90	927	19.0	76.0	61.0
11	3.25	2.02	0.64	1.23	0.28	0.50	563	18.5	50.0	45.0
12	3.20	2.22	0.61	2.16	0.22	0.85	906	16.5	71.0	41.0
E6*	2.75	1.95	0.49	1.68	0.19	0.63	335	12.5	23.0	31.0
E7†	2.65	2.24	0.50	1.33	0.15	0.60	322	14.0	26.0	34.0
E17	2.89	2.27	0.97	12.8	2.12	Cu 6.24	882	21.0	117.0	98.0
E20‡	2.32	1.33	0.50	0.19	0.04	0.30	3,082	§	‖	¶

* Annealed at 620 deg. to 635 deg. C. for 1 hr. Slowly cooled.
† Normalised at 480 deg. to 540 deg. C. for 1 hr. Slowly cooled.
‡ Cast white and annealed at 970 deg. to 980 deg. C. for 4½ hrs. Cooled at average of 30 deg. C. per hr. to 650 deg. C.
§ Did not break at capacity of machine of 40 in.
‖ " " " " " 125 ft.-lbs.
¶ " " " " " 120 ft.-lbs.

The Elements of Elementary Costing

By A SPECIAL CORRESPONDENT

[We preface this article with an explanation and an apology. We received the "first of the articles" from the managing director of one of the largest foundries in England; it was typewritten, and a note said, "I do not know where I got it." We published it as "Random Shots," and now we wish to tender our apologies to the "Radial Times" for non-acknowledgment. This second article—on the Elements of Elementary Costing—takes the subject a little further.]

When the first of these articles burst upon the engineering world, the interest and excitement were intense. The article was read and remarked on by engineers of all sorts and conditions; it was even reprinted in a well-known Foundry Periodical with the caption, "The following Outline has been written in Mr. H. G. Wells' best strain. To read it is to understand all." The author has been inundated by inquiries for information on engineering topics and regrets that he is unable to deal with the great majority of them. Especially is this so in the case of one Alexander MacPherson, of Aberdeen, for this gentleman not only forgot to enclose a stamped addressed envelope for my reply, but also forgot to stamp the envelope he sent to me. That cost me threepence and when I wrote for the repayment of this sum (my middle name being Zachariah) the letter was returned "not known."

But there was one cry from the heart which I could not ignore. Sentimental readers might immediately jump to the conclusion that it was sent in by "Black-eyed Meg," inquiring why her husband was so frequently detained in the office, but this was not the case. (Even if it was I could venture a good answer.) This particular inquiry came from "Harassed Foundry Foreman, Manchester," and it would appear that he was responsible for the casting of some slot machine bodies, but that the cost came out too high. To cap matters poor "Harassed" had to go and see the Managing Director of the firm on the only fine Saturday afternoon that Manchester has known since the war ended. (The South African war, of course.) He thought it was very tough luck, and so did I, for I retain very vivid recollections of drifting down Piccadilly (Manchester), in a punt in the Summer of 19—, this being due to the abnormally heavy rain. Readers will doubtless recollect that it was at this time that three policemen who were on night duty, and sleeping inside a doorway, were carried away by the floods and never seen again.

But I digress.

My friend "Harassed" concluded his letter by saying that, after reading my first article, he knew I was the one man to help him with good, reliable advice. How could he get to understand the mysteries of costing? He had bought a text-book on the subject and had got on all right until he had come to "logs." He got stuck at this point as the only logs he knew of were the ones that he took home under his coat every night for firewood, and he instinctively felt that these would not help to keep the cost down.

There must be many like "Harassed" who are sound practical men, knowing their craft from A to Z, but who are shaky when they come to the vast subject of Costing. It is for them that this article is written, and to avoid being too technical I will give an actual example, so that they can follow the working of the cost from beginning to end.

It was at the beginning of 1921 that I was employed at a foundry which was situated near . . . , Lancs; I am sorry that I cannot be more explicit. The firm had accepted an extremely cut price for a somewhat intricate casting, and when the order was eventually received at the office the staff hardly knew whether to laugh or cry. Instructions were immediately sent down to the foundry strictly charging the foreman thereof to keep the cost "as low as possible." How well do I recollect Mr. Smith's classic gesture: carefully twisting the instructions into the form of a spill, he lit his pipe with them. Then we breathed again, for we felt that there was a man at the helm who was capable of steering the good ship of foundry operations over the rough and treacherous roads of costing profit and loss. If any carping critic should complain that the foregoing is a somewhat mixed metaphor, I would retort that the costing process that followed was also a very mixed and twisted business. But we anticipate, as the shilling shockers would say.

Mr. Smith's first task was to work out the weight of the casting roughly, then to estimate its worth from the weight. He came to the conclusion that the casting weighed fifteen hundredweight and that it was worth twenty pounds of anybody's money. From this he decided that he could afford to have two men on the job all the week, which would have to cover all operations. He therefore put "Spike" Sullivan and "Knobby" Jackson on the moulding, instructing them to mark their time sheets, "Moulding and cores for special iron casting." The cores, however, were made by Jim Gregory, who carefully marked his time sheet, "Patching cupola"; still, as nobody in the office knew of this, everybody remained quite happy.

The job was cast on Wednesday, but here luck seemed to turn her back on the gallant foreman, for old Silas Shore, the ladleman, was ill and failed to put in an appearance for work. Now Silas had for years used the ladle as a spittoon, and had undoubtedly been instrumental in forming valuable fluxes on the metal, which dispensed with the need for soda ash or any of those newfangled ideas. The metal did not seem to run into the mould very well, and after the cast was over and the metal had cooled, it was found that three rats had taken up a temporary residence in the mould and had been unfortunately cremated.

Mr. Smith spoke very nicely; he said that he had no objection to cremation, but that, when it came to spoiling a casting worth twenty pounds for the cremation of three rats, well, he drew the line at that. Still, as Spike said, there were a darn sight too many rats about the foundry and it was a good thing that their numbers had been reduced somewhat.

Mr. Smith then took Spike and Knobby on one side and informed them confidentially that if the second mould was ready for the cast on Saturday, it would not be his fault if either of them went home thirsty from "The Moulders' Arms" on the Saturday night. A sporting offer of this sort is seldom refused by anyone in a foundry, and the mould was ready for the cast on Saturday. A piece of cheese was dangled over the mould without result, so it was decided that no fresh rats had gone into residence, and Silas poured the metal in. The casting turned out to be perfect in every detail, and it was duly fettled and despatched on the following week.

The outcome of this was that Spike and Knobby woke up on Sunday morning with a thick head apiece and that a fortnight afterwards Mr. Smith, the foreman, had a rise of five shillings on his pay slip. It will seem very mysterious to "Harassed" who will probably want to ask two questions. (1) What did the Manager say when he saw the waster casting? and (2) How was it that the cost was not double that which it was estimated at?

The answer to No. 1 is very simple. The Manager never saw the waster casting, for it was buried in a deep hole, out behind the foundry, by Spike, Knobby and the foreman, at the dead of night, aided by the foreman's dog, who kept watch, and a lantern.

The answer to query No. 2 is as follows:—Strange though it might appear, Jim Gregory again made the mistake of marking his time sheet for the core-making "Patching cupola," and the truth is *he did it on purpose*. Spike and Knobby marked their sheets for the second casting as follows:—

Thursday, 7 a.m. to 10 a.m., Repairs to 20 ton Ladle. 10 a.m. to noon, Moulding new guttering for Pattern Shop roof. (Charge to Pattern Shop.)

1 p.m. to 4 p.m., Moulding 16 firebars and 6 brake blocks for Yard loco.

Saturday, but surely, "Harassed," you have got the hang of it now?

The remainder of the costing is simple, for once the time sheets arrive at the office, the procedure is stereotyped and simple. Even with the aid of logs, the costing clerk could not make the figures show a loss, and Mr. Smith was triumphantly declared a marvel. For the information of "Harassed," I give below the final figures:—

Price received for Job, £18 6s. (lump sum).
Cost, £16 3s. 4.798d.

Finally, I should like to whisper the following remark into "Harassed Foundry Foreman's" ear. To any pukka costing clerk the figures which *follow* the decimal point are far more important than those which go before. They have an important psychological effect, for what man, on seeing the .798d. in such detail, could think of doubting the £16 3s. 4d. which precedes it?

And that, "Harassed," is that. Thank you, don't mention it.—"Radial Times."

The Impact Testing of Cast Iron

(*Concluded from page* 177.)

while a high carbon iron was the least shock resistant. Transverse resilience correlated fairly well with impact resistance, and single blow tests on machined bars correlated with transverse resilience more closely than did the repeated drop test on unmachined bars.

The few investigations which have been carried out on the impact testing of cast iron show that the methods of testing used for ductile materials, such as steel, are unsuitable for cast iron. All tests made on notched specimens, large or small, are unsatisfactory, and tests made with small specimens in pendulum machines of the Izod and Charpy type are also unsatisfactory. Large unnotched specimens tested in pendulum machines give more satisfactory results which correlate well with the resilience measured in the transverse test. Drop tests also show a relationship to the transverse resilience, and, if standardised, might be developed as a satisfactory commercial test. Repeated impact tests are suitable for determining relative toughness and resistance to shock, and are intermediate between single blow tests and fatigue tests.

As regards the impact resistance of cast iron, it would appear from the work which has been done that high carbon and high phosphorus have a detrimental effect upon the resistance. Among alloy cast iron, austenitic irons and nickel-chrome-molybdenum irons have a high impact resistance. The impact resistance of cast iron is not affected by temperature to any marked extent.

AN EXTENSION of the works of George Salter & Company, Limited, West Bromwich, has been opened for the manufacture of spring-balances and weighing machines.

Durability of Refractories*

CONSIDERATION OF VARIOUS TYPES

Refractories can be classified broadly into four distinct groups, these being in the order of increasing basicity:—(1) Acid—SiO_2; $3Al_2O_3.2SiO_2$; Al_2O_3; $SiO_2.ZrO_2$; SiC—Silica, Clay, Sillimanite, Mullite, Corundum, Zircon, Silicon Carbide. (2) Spinel—$R''O.R'''_2O_3$—Magnesia Spinel, Chrome. (3) Orthosilicate—$2R''O.SiO_2$—Olivine, Forsterite. (4) Basic—R″O—Magnesite, Dolomite. Although refractories differ so widely chemically yet in certain essentials they can be treated generally for they all have certain characteristics in common. With the exception of one or two special cases, a refractory is a collection of mineral crystals set in a glassy bond, the physical and chemical properties exhibited by the refractory depending upon the nature and amount of those two phases, the crystalline and the glassy.

Refractoriness

The refractoriness—usually designated by a Seger cone number—by itself is no indication of the durability or service behaviour of a material. The body may have a very small percentage of a low-viscosity glass which does not appreciably affect the refractoriness as determined arbitrarily but which nevertheless is sufficient to cause early failure under load. Spinel, orthosilicate and basic refractories often have this weakness. Furthermore, a highly-refractory body may or may not have high resistance to thermal shock, or spalling, and it may or may not stand up to corrosion and abrasion. The coefficient of expansion of a refractory is significant for two reasons. First, it indicates the allowance which must be left in the furnace structure to take care of the change in length occurring on heating and cooling. And second, it shows in some measure the reaction of the refractory to thermal shock. If the expansion coefficient is high, or if there are any abrupt, sudden changes there is a good chance of low resistance to spalling. This is well illustrated in the case of silica bricks. For reasonable service a refractory requires to possess a certain degree of volume stability at high temperatures. If abnormal contraction or expansion takes place the furnace structure is considerably weakened, and the opening of joints, or the formation of cracks, can lead to serious slagging and spalling troubles. The change in volume of a refractory after an arbitrary heat treatment, say 2 hrs. at 1,500 deg. C., is probably best measured by some form of mercury volumeter.

Strength under Load

In certain conditions, especially where a refractory is soaked through and through, it may suffer serious deformation, and the strength/temperature characteristics can assume considerable importance. In practice, the strength under load can be arbitrarily determined by subjecting a standard specimen to a known load, raising the temperature continuously, and recording the dimensional changes of the test piece. For positions calling for very high under-load strength a brick should show less than 1 per cent. subsidence at 1,600 deg. C. under a load of 25 lbs. per sq. in. when heated at a rate of 10 deg. C. per min. Refractories which show excellent under-load resistance are those of the acid group, notably silica, sillimanite, mullite and corundum. As already pointed out the development of a low-viscosity bond can be a source of considerable weakness in a brick. In this respect lime-magnesia silicates are capable of forming very fluid liquids and their elimination is one of the chief problems in the manufacture of the non-acid refractories.

The temperature gradient in a refractory has an important bearing on this question. For example, good firebricks can often be used with hot face temperatures up to 1,550 to 1,600 deg. C., provided one face is kept cold, thus giving a temperature gradient which ensures only a small portion of the bricks being in the deformation region. Otherwise, firebricks, if subjected to complete soaking, such as in piers and division walls, are not capable of resisting much load above 1,450 deg. C.

Thermal Shock

The sudden heating or cooling of a refractory can set up considerable stresses, and these are often relieved by the formation of cracks, considerable portions of the material frequently being completely detached. In practice this is probably the commonest cause of failure. Certainly it is always a most annoying occurrence. Bricks showing very high or irregular expansion, such as magnesite or silica, are notoriously bad for spalling. Also bricks which have little structural flexibility, such as fusion-cast materials and those which have been heat-treated to produce abundant glassy material, usually show poor resistance to thermal shock. And poor thermal conductors with extremely low strength, such as the new types of high-temperature insulation bricks, have low resistance to spalling. In recent years some outstanding non-spalling refractories have been produced, examples of these being sillimanite (or kyanite), special magnesite and chrome-magnesite, and special fireclay bricks.

There is no generally recognised spalling test. Good indications can be got by suddenly heating the end of a brick to about 1,250 deg. C., holding 1 hr., and suddenly cooling in an air blast. A good non-spalling brick after 20 cycles will show no loss; a very good one will neither show loss or cracks. However, under service conditions the spalling resistance of a refractory may be considerably reduced. A frequently occurring failure can be caused by the formation of zones of weakness in a brick. Fireclay bricks at very high temperatures, or with long soaking under reducing conditions, may become considerably vitrified, and the vitrified portion can crack nor leave the body of the brick very easily. The diffusion of fluxes into a refractory may considerably modify the constitution and form very definite zones which have different physical characteristics. Such transformations are a source of weakness, and are often seen in silica bricks which have been exposed to fluxes. Finally, the adherence of layers of slag with either a much higher or lower coefficient of expansion than that of the brick can be a source of trouble, causing the brick, if subjected to temperature fluctuations, to have its bond broken and be completely disrupted or else to be distinctly cracked.

Corrosion and Abrasion

In metallurgical work the fluxing and abrasion of refractories is a serious problem, and it is often cause for wonder that bricks last as long as they do. For severe corrosion and abrasion it is accepted that bricks should be dense, impermeable, and tough or well bonded, at working temperatures. The ideal is special fusion cast or sintered refractories, impermeable and with practically no porosity. These materials, however, are very costly, and, apart from the fact that they are often sensitive to spalling, the problem usually resolves itself into a question of pure economics.

The effect of corrosion varies according to the type of refractory. If the material is dense and impermeable at working temperatures, the slag either builds up on the surface of the brick or flows away. On the other hand, if the brick has an open texture, the slag is absorbed and zones of varying composition can be formed. Or, again, the brick and slag may form an intermediate layer of high viscosity and in certain conditions the slag can become a decided nuisance by its growth and accumulation.

Naturally, the degree of corrosion is also dependent upon the type of slag or flux, and the viscosity of the slag, and more particularly that of the slag-refractory reaction product, seem to be controlling factors in the rate of consumption of the refractory. That the formation of a thin, fluid reaction product means rapid destruction is well seen when magnesite, dolomite or lime reacts with fireclay. Or, again, when ordinary bottle glass, which is in effect an acid slag, is in contact with magnesia spinel, which is also more acidic than basic. In this instance the viscosity of the reaction product is not sufficient to prevent the flow and loss of the liquid through the refractory.

To varying extents this question of corrosion is connected with that of abrasion, and for high resistance to physical disintegration a refractory must be tough and well bonded. At this stage the two deeply-opposed characteristics of refractories are brought into sharp contrast. Generally, resistance to spalling demands loose bonding, and resistance to corrosion and abrasion requires the particles of the refractory to be well knit and bonded together.

Nature of Atmosphere

The durability of refractories is often adversely affected by the nature of the atmosphere in which they are in contact. Special conditions arise when the furnace atmosphere is rich in carbon gases, sulphur gases, hydrogen or steam. Firebricks which contain free iron oxide, due to inadequate burning, are easily and completely disintegrated by carbon gases. For example, between 430 and 470 deg. C. carbon monoxide in the presence of iron oxide in a lightly-fired brick freely deposits carbon, the growth of which sets up sufficient force to cause complete disintegration. In addition, firebricks at higher temperatures are sensitive to reducing gases, for the rapid production of ferrous iron accelerates vitrification, and this is usually undesirable. Chrome bricks also can show erratic behaviour under reducing conditions, varying increases in expansion occurring between 700 and 1,000 deg. C., depending upon the nature of the original ore. At considerably higher temperatures the iron and chromium oxides can be reduced to form a metallic alloy.

Fluorine- and chlorine-bearing gases have also a pronounced effect on refractories. Even in small amounts they act as mineralisers, reducing the viscosity of the glassy bond and promoting crystal growth. Another possible effect of the furnace atmosphere is the influence it may have upon a slag either by keeping the iron largely in the ferrous condition or else by giving additional fluidity due to the absorption of sulphur, fluorine, chlorine or perhaps water vapour.

Conclusion

Refractories have definite limitations, and even under well-controlled conditions there is always a measure of anxiety concerning their durability. This can be reduced to a minimum by using the right type of material, chemically and structurally considered, for known conditions and positions. Each case needs careful consideration and the obtaining of suitable refractories almost invariably entails the use of several types of bricks in the same furnace. It is rather dangerous to be prophetic or dogmatic about refractories, but in general the following materials have certain definite characteristics.

Silica.—Good under-load; poor thermal shock.

Corundum.—Good under-load; good thermal shock.

Sillimanite.—Good under-load; good thermal shock.

Chrome.—Poor under-load; poor thermal shock.

Spinel.—Good under-load; good thermal shock.

Magnesite.—Poor under-load; poor thermal shock.

(*Concluded on page* 182.)

* From an article in "Metal Treatment" by J. F. Hyslop.

Removal of Moisture from Compressed Air

By I. L.

It is well known that atmospheric air usually contains a variable amount of water in the form of aqueous vapour. The maximum quantity of this aqueous vapour which a given volume of air may contain depends on the temperature and pressure of the air. When this maximum quantity is present the air is said to be saturated, and when any amount less than this maximum is held in the air it is said to be partially saturated. The relative degree of saturation at any time is determined in practice by a hygrometer, and is usually expressed as a percentage in terms of relative humidity.

The moisture capacity of atmospheric air is dependent partly on the temperature, and in Fig. 1 the effect of temperature change on the moisture content of the air is shown graphically. This applies to fully saturated air. It will be observed that the curve rises steeply, showing that temperature has a very considerable influence on the moisture capacity of atmospheric air. The amount of water vapour entering a compressed air system during summer conditions is thus likely to be much greater than it will be during average winter conditions. For example, suppose average summer conditions be represented by an average humidity of 75 per cent. at a temperature of 75 deg. Fah., and suppose the corresponding figures for average winter conditions are relative humidity 50 per cent. and the temperature 40 deg. Fah. The weight of water vapour contained in 1,000 cub. ft. of air under the assumed summer conditions will be 1.25 (taken from the graph at 75 deg. Fah.) × 0.75 (representing percentage humidity) = 1 lb. Similarly for winter conditions it will be 0.35 × 0.50 = 0.17 lb. Thus, under the assumed winter conditions the weight of water vapour admitted is slightly less than one-fifth of that entering the system during the summer. In this connection a case described to the writer might be mentioned.

During the severe weather conditions last winter much trouble was experienced on a certain plant with the freezing of exposed compressed air lines, and a meeting of operatives was held to discuss remedies. One man suggested that the quantity of intercooler water circulated be decreased so as to put out the air at higher temperatures, which he thought would decrease the possibility of freezing. It was very difficult to convince him that this natural thought was incorrect. Actually, as shown by the curve (Fig. 1), more water would be thrown into the air lines, thus raising the dew point and aggravating the condition so that more freezing would occur. The troubles were lessened by increasing the slope of the pipe towards the drip points, and by lagging exposed sections of the piping. This, however, is by the way, but it serves to emphasise that in consequence of the physical changes which the air undergoes during compression and subsequent cooling the bulk of these weights of water vapour will be deposited, in the form of free water, in the transmission system. Water pockets will be formed at low-lying sections, thereby greatly reducing the cross-sectional area of the pipe-line at such points and therefore increasing the frictional losses. Additional disadvantages are probable damage to pipe joints and increased leakage losses. Water hammer with its associated evils is another likely occurrence. Lastly, and of most importance, water entering the compressed air motors may result in smashing the air cylinders, damaging the piston, valves or valve seatings, or cause serious freezing troubles.

The effect of pressure changes on the moisture capacity of air has also to be considered. At a given temperature a certain *volume* of air cannot hold more than a certain *weight* of vapour. Thus, if at a definite temperature two cub. ft. of air are compressed into 1 cub. ft.—then the aqueous vapour in the reduced volume will be only one half of the original amount; similarly, when n cub. ft. of air are isothermally compressed (*i.e.* compressed with the temperature constant) into $\frac{1}{n}$ th cub. ft., the original aqueous vapour content will be reduced to $\frac{1}{n}$th. In other words, the weight of aqueous vapour which compressed air can hold, compared with the weight required to saturate this air before compression, is reduced in the inverse ratio of the absolute pressures, provided the temperature is kept constant. For example, if air pressure in a receiver be 30 lbs. per sq. in. (gauge) and the air in the receiver has been cooled down to suction temperature, then the receiver air will hold only $\frac{15}{30 + 15} = \frac{1}{3}$rd of its moisture content before compression. That is, if the suction air was fully saturated then probably two-thirds of the originally moisture content would be precipitated in the receiver.

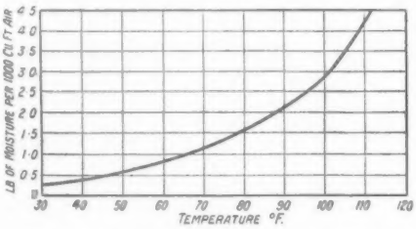


FIG. 1.—SHOWING INCREASE OF MOISTURE CONTENT WITH INCREASE OF TEMPERATURE.

Practical Application

In air-compressors the changes of the physical state of the air being compressed do not take place separately; generally pressure is increased, volume is reduced and the temperature increased simultaneously. If the air could be compressed isothermally only pressure and volume changes would occur and moisture would be deposited in the compressor cylinder. If the other extreme occurred, *i.e.* adiabatic compression, the increase of temperature would be more than sufficient to counteract the effect of the pressure increase so far as the moisture-holding capacity of the air was concerned, and therefore no water would be deposited during the compression stage. Actually, compression takes place under conditions which are neither adiabatic nor isothermal. Without going into details of calculation, it may be said that the air in the compressor is able to hold much more moisture than it originally had, and consequently no deposition of moisture occurs in the cylinder of the compressor. If, however, freezing troubles at exhausts and in the transmission system are to be avoided, as well as the other consequences of water deposition as outlined above, this water content of the air must be removed.

There are three general methods of collecting and draining off moisture from compressed air systems, *viz.*, receiver or after-cooler method; water separators with or without automatic drainage, and drain cocks.

Apart from other functions, the air receiver serves to reduce the temperature of the air, and thus water is deposited. The reduction of temperature effected in the receiver will depend upon its capacity. When such capacity is insufficient to allow the air to be cooled down to, say, nearly 80 deg. F., an after-cooler should be fitted. Essentially, this is similar to the inter-cooler and it is placed between the outlet from the compressor and the inlet to the receiver. Sometimes, the receiver and after-cooler are combined in one and the same unit.

The precipitation of water from the air is facilitated when the normal air flow is subjected to turbulence created by its impingement on some surface which causes a change in direction of flow. In the after-cooler the passage of the air between the tubes carrying the cooling water causes the moisture to be deposited on the outsides of these tubes whence it runs to the lowest point in the containing vessel. A drain cock is provided for its outlet. In the simple receiver the only air turbulence set up is by the air itself in its passage through the receiver. There is little impingement of the air on the walls of the receiver. It often occurs, therefore, that all the moisture which should be deposited in the receiver due to the temperature drop does not do so, and a portion of it in the form of mist or spray is carried into the transmission system by the air leaving the receiver. Simple means are available for preventing unnecessary water being carried forward into the pipe-lines in this way; for instance a water-separator may be inserted in the main pipe line at an accessible point.

Water separators suitable for compressed-air systems are generally modifications of steam traps used in steam transmission to ensure that clean, dry steam is supplied to the engines or plants wherein the cleanliness and dryness of the steam are important. All the numerous designs of these devices possess two common features, *viz.* (*a*) the normal direction of flow is disturbed so that the water particles carried in suspension by the air current are arrested or thrown centrifugally out of the air flow, and (*b*) the separated water is prevented from coming into contact with the main flow of air again. The problem is thus essentially similar to that of removing water from steam.

The separation of free moisture from the compressed air flowing through the system is, however, only one part of the water problem. The other is to effect the discharge of the separated water without leakage of the compressed air. The general methods of doing this are to collect water in receivers and periodically release it, and the use of automatic traps.

Water Collection

Water collection in receivers involves the release of the accumulated water at intervals. When the rate of accumulation is variable, as it inevitably is, it is difficult to provide the necessary attention for periodic drainage, and as a result the storage capacity of the receiver will probably be taxed to such an extent at times that water may be forced downstream and so be passed on to the air motors, etc. A simple and effective method of combating this is to leave the receiver drain cock always slightly open, but this has the disadvantage of invariably allowing air leakage. This is undoubtedly a wasteful method and it is probably best to provide receivers likely to accumulate during, say, a shift, and to discharge the water either at the beginning or end of such shift.

For the discharge of separated water through automatic traps, several designs of trap are available, and provided attention is given at regular intervals to their maintenance they function quite successfully. To minimise irregularities in the working of any kind of automatic

(*Concluded on page* 182.)

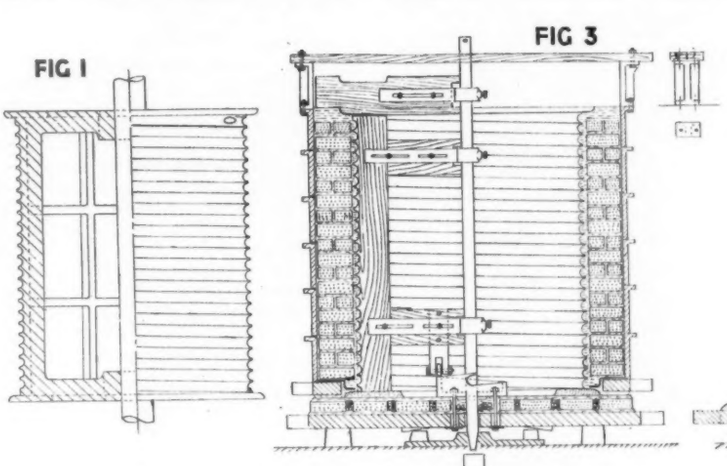
Moulding a Large Crane Barrel with Spiral Rope Grooves

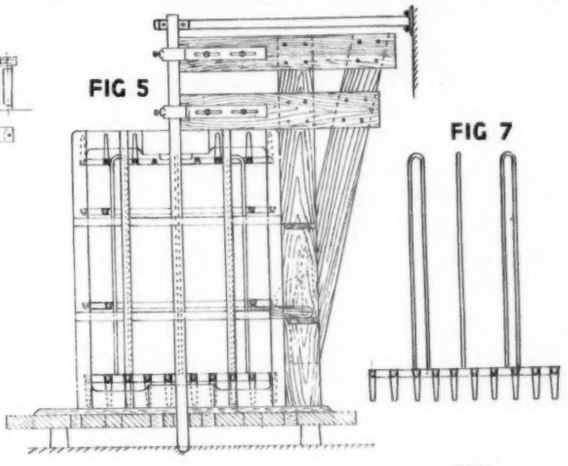
By F. OLDERSHAW

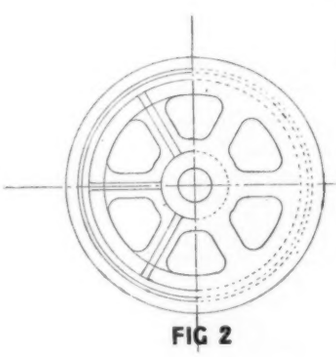
The object of this article is to explain the method adopted in the making of a casting, the half sectional elevation and plan of which are shown in Figs. 1 and 2. The size of the drum is 5 ft. dia. over the grooves and 6 ft. 3 in. long.

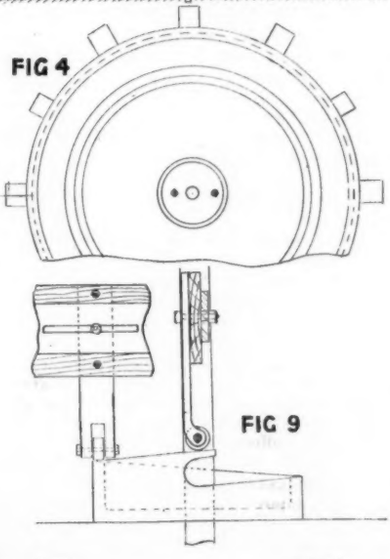
Patterns

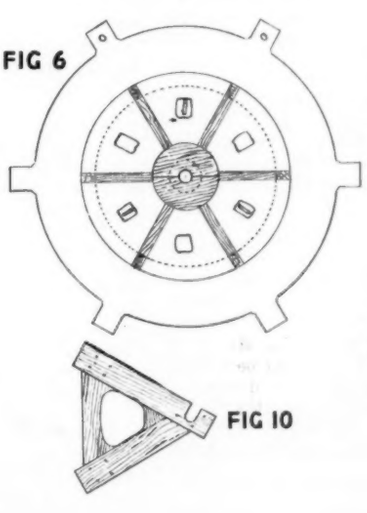
The first things to consider are the patterns; these will consist chiefly of loam strickles ribs and internal flange segments for the body core, and a pattern for the helical race. This latter portion is most important since it determines the pitch of the spiral and carries the striking board up and down as it is revolved around the centre spindle. The rise of the helical race depends upon the grooves on the drum, and the distance between the lowest and highest points measured on the centre line (Fig. 9) will be the same as the distance between the grooves, and is known as the pitch. The pattern for this race must be very accurate as any untruth on it will be exaggerated on the grooves. A pattern will be required for the carrier arm which carries the small roller, and is attached to the bottom spindle-arm and board by bolts. Three boards are required; one to strike the bed on the bottom plate; one to form the dummy flange at the bottom, this is made double-sided and therefore may be used to form the top flange (Fig. 3), and another for the body which carries the grooves. The board for the body core consists of a double battened and cross braced board and must be perfectly rigid on the spindle. Two setting pieces are screwed on to it, and a pivoted strip, shown in Fig. 5, is attached and serves to form a bed for the internal flanges, whilst it can be turned up to pass the upright ribs. Two boss-patterns, with holes through the centre to fit snugly on the spindle, are marked with centres against which the radial ribs are set. A core-box (Fig. 10) fits over the spindle and forms the cutting through cores at each end of the drum.

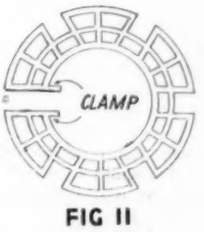












Tackle

The tackle required will be a bottom plate, lifting ring with short brods and the necessary handles or lifting lugs, bricking up rings or cope binders, steadying bar and brackets to secure top of spindle, top-plate, lifting-grid with staples and brods, binder grids and crown grid with brods. A casting is made from the pattern for the helical race, and the hole in the centre is bored out; a working fit on the spindle and the arm carrying the roller are fitted up ready to attach to the spindle arm and board. The spindle arms used on the grooved board must be a nice sliding-fit on the spindle as the clamping studs will have to be loose to allow the arms to move up and down as the board is revolved. The spindles used may be either bull-nosed or tapered at the bottom and fitted with suitable centre plates.

Moulding the Bottom Bed and Cope

The centre plate for the spindle is first bedded down in its place and levelled. Three foundation plates are set and on these are placed three iron packing blocks or half cwts. These packings are levelled up by placing a straightedge and level from one to the other. The bottom plate is then placed on these packings with the centre hole directly over the spindle hole. The spindle is inserted, and to this a straight striking board is attached by bolting to a spindle arm. This board should be squared up to the spindle to ensure a perfectly flat bed. If this bed be not flat the error may be rectified by slackening the clamping bolts and readjusting the board. Before placing any bricks on the bottom plate the distance between the plate and the striking edge of the board must be determined by setting one brick and allowing for about 1½ in. of loam on top of the brickwork. The plate may now be covered with brickwork, leaving spaces between the bricks to be filled up with ashes or small coke as shown in Fig. 3.

These ashes must be rammed between the bricks, and where they come to the outside of the plate they must be left exposed to allow the gases generated during casting to escape. On top of the bricks and ashes a thin layer of straw may be laid, and the whole bed splashed over with loam and water mixed to the consistency of slurry. Above this is rammed a bed of loam or core sand, which is roughly strickled off with the board, and finally, a coat-

ing of loam is well rubbed on and the bed finished by slipping up with soft loam which has been passed through a fine riddle. The board is removed and the core print for the centre core is bedded in position over the spindle and two holes are made by means of a runner cutting tube to allow for the bolts which will be required to secure the helix-race casting.

The bed is then dried either by stoving or fires *in situ*. When sufficiently dry, to sustain the weight of the mould, the board which forms the top flange and joint on one edge, and the dummy for the bottom flange on the reverse edge, shown in Fig. 3, is set in position and the sand dummy is rammed on the bottom bed and strickled to shape. The dummy may be covered with parting sand or well dusted with parting powder to make removal easy when the mould is parted. The helical race is then placed in position with the spindle passing through the centre, and is secured by means of two bolts as shown in Fig. 3.

The main body board is now set up and the carrier arm bearing the roller is fitted to the bottom arm and securely fastened in position with the board and roller at their lowest points directly underneath the overlap of the highest point of the race. Thus when the board is revolved it will move upwards towards the highest point. An enlarged view of this is given in Fig. 9. It is advisable to allow the patternmaker to set this tackle.

When the board and tackle have been set, the next operation is to place the loam on the joint and over the dummy flange, and after clay-washing the bottom of the lifting ring or drag, this is bedded in position and gaggers are fixed to carry the stiff loam placed over the bottom flange. The cope rings are placed in position on the lifting ring and the mould is bricked up leaving the necessary clearance between the bricks and the board. The top course, directly under the top flange, should be built with loam bricks or a space of about 4 in. rammed up with core sand or stiff loam to allow for the contraction between the flanges during the cooling of the casting. When the brickwork has been put in, the top board is set in position by using a staff on which should be marked the length of the mould.

The same board that was used for the dummy flange is reversed and used for the top joint and flange. The reason for using a separate board for the flange and joint is obvious, since if the bodyboard was used for this purpose, the top flange and joint would follow the spiral instead of being flat.

Making the Grooves

To form the grooves the loam is rubbed well on to the bricks and the whole of the inside of the mould roughened up. When the loam has stiffened sufficiently the finishing slip is mixed and passed through a fine riddle, and the grooves, top flange and joint are slipped up. The boards, spindle and race tackle are removed and a fire may be placed in the mould or the whole mould placed in the stove and allowed to dry sufficiently to allow it to be parted at the bottom joint for the removal of the sand forming the dummy flange and also for blacking to be carried out.

Before the cope is lifted from the bottom part a series of locating marks should be put on the joint to make sure of replacing in the same position when closing the mould. After the cope has been removed the bottom bed is cleared of all sand forming the dummy, the centre core print removed to the necessary centre lines for setting, the cutting-through cores are located and the core box laid in position. In each of these six cores it is advisable to place an iron packing to come level with the top of the core to take the weight of the body core and prevent any crushing which may be caused by the weight of the core resting on sand only. The outside or cope, after drying, is dressed and blacked, and after the cores on the bottom bed have been dried the whole bottom part is blacked and dried ready to receive the cope.

Main Body Core

The body core is made on the top-cake plate, which is levelled and set as usual and by using a straight board and spindle. The procedure is the same as for a flat top. The top plate should contain the runner and riser holes and holes to allow the vents from the body core to be brought through the six cutting-through cores and hence through the top plate. After drying, the plate is reset, the spindle placed in position, and the boss pattern placed on the bed over the spindle. The board is set up and firmly secured, and a line is marked on the bed in the form of a circle corresponding to the diameter of the core. This circle is then divided into six segments and the six cross ribs are set as in Fig. 6. These may be secured against ramming out by inserting a few sprigs. The bed is covered with parting sand and between the ribs a quantity of stiff loam is placed. The spindle and board are then removed, and the lifting grid similar to that shown in Figs. 7 and 8 is claywashed and placed in position, using pieces of packing to prevent the brods protruding through the bottom of the core.

The spindle is replaced and secured at the top, and the spaces between the ribs are rammed up with stiff loam, inserting gaggers if required. When rammed up to the top of the lifting grid it is advisable to put in plenty of vents with a stout vent wire to help the steam to escape during drying.

Bricking up may now proceed, leaving spaces for the upright ribs, which are located by the ends of the cross ribs. Plenty of loam bricks should be inserted in the brickwork between these ribs, and the brickwork in the middle of the core should have the spaces between the bricks filled with ashes or other dry material and well rammed in. When the brickwork has nearly reached the first internal flanges between the ribs, the upright ribs may be set and rammed up in position with stiff loam or damp core sand.

The bed for the internal flange is formed by the pivoted strickle shown in Fig. 5; it is worked in position between the ribs and is then swung clear to pass the rib, and the next piece of bed is made in the same manner. The pivoted strickle is then removed and fixed in position opposite the top set of flanges. When the pieces of flange have been placed in position they are covered with loam, and on this is bedded a binding grid, which is made with a slot as shown in Fig. 11 to enable it to be placed in position without removing the spindle and board.

Bricking up continues as described until the next set of flanges is reached; these are fixed in the same way as the lower set, using another binding grid over the flanges. When nearing the top of the core allowances must be made for the crown grid which comes under the boss and cross ribs. This grid carries brods and is made with a slot to enable it to be fixed without disturbing the spindle and board. When in position, clamps are placed across the slot to prevent any spring or expansion in the grid during drying. This also applies to the binding grids, which should be secured in a similar manner.

The centre boss is then bedded in position, and to get this boss in place it should be in two parts, split across the middle as shown in Fig. 6. The cross ribs are set and the space between the ribs rammed or bricked up but leaving holes for vents and for lifting hooks which should come directly under the top set of cutting-through cores. When all the ribs have been rammed up the core is roughed up with loam and after being allowed to stiffen up, may be finished by slipping with soft loam.

The spindle and board may now be removed, the top boss, ribs, and flange segments withdrawn leaving the bottom boss and crossribs to be removed after the plate and core has been stoved. After drying for one night the core is lifted and the boss and ribs taken out, the core can then be put back on the top plate or on to a level dry-sand bed and completely dried. When dry, the core is dressed; the fillets rubbed on the ribs, and the whole core blacked and dried. The centre hole left by the spindles should be plugged at the bottom and after setting the centre core in the print in the bottom of the mould the body core is carefully lowered into position making sure that the thickness is equal round the periphery.

The six cutting-through cores (which have been made with a hole through the middle to allow the vents to be brought through) are secured in position with core gum; the top boss core is located in the print, and after boring the runners and risers in the top cake plate, the mould is finally closed, making sure that the joints touch over as large an area as possible. Vent tubes are brought through from the ashes in the core and well caulked in by ramming with sand and as an extra precaution against "lift" in the core, the tops of the staples in the lifting grid may be packed and weighted. The whole job is bolted down, and when the runner bush and rises are prepared the mould is ready to cast.

Durability of Refractories

(*Concluded from page* 179.)

There seems no chance of a big improvement in the spalling resistance of silica, for the cristobalite and tridymite transformations between 200 deg. and 300 deg. C. are an inherent source of weakness. The other poor thermal-shock bricks, such as chrome and magnesite, can be helped by alterations in the constitution of the bond and by grading to give flexibility of structure. Finally, although the more spectacular advances in refractories have been in the special types, such as sillimanite, corundum and magnesia-chrome spinel, yet definite progress has been and is being made in the ordinary fireclay materials, and the characteristics and uses of the specific types of these are now becoming well known and established.

Removal of Moisture from Compressed Air

(*Concluded from page* 180.)

discharge trap, a filtering device is almost essential. Water collected in pipe lines, when finally picked up and carried along, loosens pipe scale, rust and dirt from the inside of the pipes. If these materials enter an automatic water trap they will cause excessive wear in the valve and valve seatings of the trap; and as a result the useful life of the discharge valve and its seat are greatly impaired and air leakages result.

In the cold spell last winter the author experienced much trouble in freezing of compressed air lines. This, of course, was due to moisture collecting in the lines and freezing at the low prevailing temperatures. Freezing trouble in the use of compressed air may also result in normal weather owing to the co-existence of two factors—moisture in the air, and the lowering of the exhaust air below freezing temperature. Much freezing at the exhaust ports of air engines, etc., has been traced to this combination. The most effective way in which such trouble can be combated is by removal of the water by measures such as those outlined above; apart from trouble-free operation, more efficient and economical utilisation of the air is obtained.

BARON INVERNAIRN OF STRATHNAIRN, better known as Sir William Beardmore, formerly chairman and managing director of William Beardmore & Company, Limited, chairman of Alley & MacLellan, Limited, Beardmore Diesels, Limited, and other companies, left personal estate in Great Britain and abroad valued at £858,092.

Vitreous Enamelling Section

Opacifiers in Wet and Dry Enamels

By Dr.-Ing. LUDWIG STUCKERT (Technische Hochschule, München)

(*Concluded from page* 110.)

Opacity of the Enamel

All the effects on the mechanical and chemical properties described hitherto must be relegated to the background in comparison with the optical influence of the opacifier on the enamel. Even the most outstanding improvement of all the properties of the enamel could not save an opacifier from extinction if it failed in this respect. On the contrary, the most widely used opacifier is that which, besides possessing good opacifying and heat-resisting properties, influences most favourably the remaining properties of the enamel. On account of its fundamental importance, the heat-stability of the opacification produced by the various media will also be dealt with in this section.

The opacity of an enamel depends primarily on the difference in refractive indices of the enamel melt and opacifier respectively, corresponding to Fresnel's law,

$$I_r = I_e \frac{(n_2 - n_1)^2}{(n_2 + n_1)^2},$$

where I_r represents the diffuse reflected light, I_e the incident light, n_1 the refractive index of the glass melt, and n_2 that of the opacifier. Besides these optical constants, the shape and size of the particles of opacifier, and thus the number of optically heterogeneous surfaces, exercise a mathematically calculable influence on the total opacification. At the same time, the chemical attack of the enamel on the opacifier also plays its *rôle*, which in general opposes the opacifying action, inasmuch as it vitrifies a portion of the opacifier, and so reduces its effective concentration. In contrast with the optical action, this chemical action can hardly be calculated mathematically. From the opposed interplay of optical heterogeneity of the enamel, and chemical interaction between enamel and opacifier, the state of affairs in technical opacification finally arises. Further, there is usually an opacity contributed by the so-called pre-opacifiers, to which the opacification due to the opacifier proper is added. In the course of the investigation it will be shown, however, that during the enamelling process itself a supplementary opacification can arise in the enamel, in addition to the effect of the opacifier.

To determine the opacifying power, the enamel slips were weighed out on to ground-enamelled plates (80 by 60 mm., with a raised rim 3 mm. high), and distributed as uniformly as possible by tipping up and tapping the plate. The stiff enamels with "Z" and the strongly "running" enamels caused certain difficulties here, the latter occasionally collecting in recesses. The weight of the plates was fairly uniform, and varied between 40 and 45 grms. With such small variations, irregularities in the result of the enamelling through uneven temperature of the furnace are avoided. The amount of the slip was such that on each plate there was 5 grms. of the opacifier-free enamel mix. The coating weights thus arrived at were:—

Opacifier:	0	2	4	6	9	10	12 per cent.
Weight of coating:	7·45	7·60	7·75	7·90;	8·10	8·20	8·30 grm.

The enamel was fired in an electrically-heated muffle furnace, in a neutral furnace atmosphere. Heating was effected by a winding of chrome-nickel strip, which heated bottom, roof, side walls and back of the muffle space uniformly, and made possible a uniformity of temperature in the furnace which could never be obtained by gas heating. The setting of the furnace to the required temperature was quickly done, and small temperature variations could very rapidly be corrected by regulating the current. The plates were fired singly, in the centre of the furnace under the welded junction of the Le Chatelier thermo-element, at a temperature of 850 deg. C. for enamel A, 840 deg. C. for enamel B, and 850 deg. C. for enamel C. As soon as the test pieces showed the correct glaze, they were taken out of the furnace. Four test plates were fired from each enamel slip. The firing of enamels, the opacifiers of which act partly or completely by the separation of gas bubbles, requires special care. These very easily inclined to "boiling out," especially at elevated temperatures and with higher additions of opacifier.

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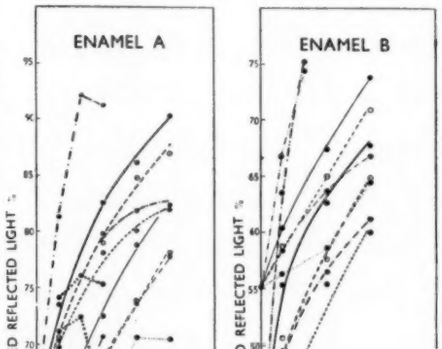

FIG. 6.—OPACIFICATION OF ENAMELS.

The comparison of the intensity of opacity was first carried out visually. In this way, however, only qualitative differences can be recognised; a quantitative measurement of the opacifying effect is impossible. Even the qualitative differentiation becomes difficult when opacities of almost equal intensity are concerned, as was very frequently the case with the enamels in question. The quantitative comparison of opacity is best effected with an optical opacimeter, either the Ostwald half-shade apparatus, or the Zeiss photometer. Both permit also of the measurement of the lustre of the samples. In the present case, the Ostwald apparatus was used. The determination of the opacity was based on four measurements of each test plate, so that the final result was the mean of 16 individual measurements. The results for the different enamels are collected in Tables V and VA, and set out graphically in Fig. 6. From these tables and curves the following conclusions may be reached.

Of the opacifiers at present in technical use, stannic oxide has the greatest opacifying power. At all concentrations it leads to the highest possible opacifying effect, which is attained with both pre-opacified and transparent enamels. Next, but some way after, comes W, to which the antimonates approximate fairly closely, especially with low additions; higher additions, however, give less satisfactory results. The mixed opacifier X is much less efficient. Even the addition of 12 per cent. does not suffice to attain the opacifying effect of 6 per cent. of stannic oxide, so that its use results in no economy. Further, by the use of this medium all the advantages, which are associated with the use of stannic oxide as regards bending strength, thermal resistance and acid resistance of the enamel, are lost.

Three years ago the author showed that, according to theory, the curve for the difference quotients of the opacity must follow a logarithmic course, *i.e.*, that the logarithms of the quotients, determined from the opacity curve, must bear a linear relation to the amount of opacifier added, in accordance with the equation,

$$\log \triangle T = K_1 + K_2 m,$$

where T signifies the opacity, K_1 and K_2 are constants, and m is the concentration of opacifier. This agrees well with the behaviour of stannic oxide in enamel A, although other effects are superposed. With enamel B agreement is not so good, but in this case special conditions obtain, to which we must return later.

The gas opacifier "Z" may now be briefly considered. It cannot be applied to the usual pre-opacified enamels of the industry, but requires a special transparent enamel, the composition of which is kept secret. The maximum opacifying effect obtainable with "Z" amounts to 76 per cent., with an addition of 4 per cent. of the opacifier. The same effect is obtained, on the other hand, with a moderately pre-opacified enamel mix by adding 3 per cent. of stannic oxide to the slip.

The opacifying effect of stannic oxide is exceeded only by that of cerium oxide, which is considered in more detail below. To estimate the value of an opacifier, in addition to its effect with normal firing, its behaviour on overfiring the enamel must also be considered. In practical working, it is impossible to avoid the exposure of objects standing near the walls and in the rear parts of the furnace to more prolonged firing than those in the middle or fore part of the furnace. Hence, heavy demands are made on the heat stability of the opacifiers towards the end of the firing process. If they do not possess the necessary resistance, they vitrify

more or less, and diminish greatly in opacifying power. The lustre also decreases markedly, and the enamels become dull. In many cases, however, intensive gas evolution occurs, the enamel becomes foamy, and finally boils out in large bubbles.

To test this heat stability, two normally-fired plates were exposed for a further two minutes to the firing temperature, and again tested for lustre and opacity in the Ostwald half-shade apparatus. The results are given in Tables V and VA, and represented in Fig. 6 by the lightly-drawn curves. It will be seen that stannic oxide again maintains its pre-eminent position. The opacity diminishes on the average by 8.5 per cent., of which about 6 per cent. is to be regarded as decrease in opacity of the enamel melt, and 2.5 per cent. as vitrification loss of the stannic oxide. The diminution with antimonates is of the same order of magnitude, and with mixed opacifiers even greater. "X" in particular diminishes in opacifying power so much by overburning that it can hardly be further regarded as an opacifier. With careful normal firing, cerium oxide gives the most outstanding opacification with enamels A and B, as has already been mentioned, exceeding even that of stannic oxide. By overfiring, however, the opacity with enamel A falls below that of stannic oxide, with simultaneous "boiling out" of the enamel.

TABLE V.—*Opacity and Lustre, Enamel A.*

Opacifier.	Per cent. addition to mix.	Normally fired enamel.			Overburned enamel.			Difference in opacity.	Mean.
		Opacity per cent.	Relative lustre number.	Mean lustre number.	Opacity per cent.	Relative lustre number.	Mean lustre number.		
—	0	64.6	25.8	25.8	58.6	23.4	23.4	6.0	6.0
SnO_2	2	73.5	26.8	—	64.7	27.5	—	8.8	—
,,	6	82.6	29.1	27.8	72.5	24.8	26.2	10.1	8.5
,,	9	86.2	28.1	—	78.8	25.4	—	7.4	—
,,	12	90.3	27.3	—	82.7	26.8	—	7.6	—
"W"	2	70.6	22.1	—	61.4	27.6	—	9.2	—
,,	6	79.0	23.5	24.0	67.7	25.3	26.6	11.3	10.1
,,	9	84.8	25.1	—	73.9	26.1	—	10.9	—
,,	12	87.0	25.4	—	78.2	27.4	—	8.8	—
"X"	2	69.7	24.0	—	63.9	26.9	—	5.8	—
,,	6	78.1	25.9	25.0	64.5	27·8	25.4	13.6	10.1
,,	9	80.1	24.1	—	70.6	23.5	—	9.5	—
,,	12	82.0	26.1	—	70.5	23.5	—	11.5	—
"Y"	2	70.3	26.8	—	63.6	26.4	—	6.7	—
,,	6	79.8	25.6	27.2	68.4	27.9	27.9	11.4	8·0
,,	9	81.8	28.2	—	73.7	28.3	—	7.1	—
,,	12	82.4	28.1	—	77.8	29.2	—	4.6	—
CeO_2	2	81.3	34.2	—	65.7	29.8*	—	15.6	—
,,	4	92.1	38.6	38.1	66.1	28.5*	28.5	26.0*	20.9
,,	6	91.2	41.3	—	70.8	27.2*	—	20.4	—
"Z"	2	74.1	32.7	—	71.1	25.4†	—	2.4	3.0
,,	4	76.0	37.7	35.9	72.4	23.2†	24.2	3.6	—
,,	6	75.3	37.4	—	64.7	24.6*	—	10.6	—

* Boiled-out enamel. † Foaming enamel.

With enamel B the conditions are considerably more complicated. From the tables and curves it may be seen that with this transparent enamel the opacity rises on overburning, instead of falling as usual. First, the enamel B, fired without any opacifier, shows a sudden increase of not less than 22 per cent. on overburning. With the enamel slips mixed with the most widely differing opacifiers this upward jump is much smaller, amounting on the average to only 7 per cent. These enamels thus acquire through overburning an additional opacification from the enamel melt itself. To explain this phenomenon it must be remembered that every enamel is a substance in a state of non-equilibrium, in which the state of solution existing at about 1,100 deg. C. is maintained by the chilling of the granulated melt. In particular, with fluorides a state of supersaturation must result, which is corrected by the prolonged keeping of the enamel at its melting point, and probably brings about the separation of sodium fluoride with an increase in the opacification. It may be recalled that Agde and Krause[16] obtained their fluoride opacities by tempering such transparent enamels. That the increase in opacity of the enamel, to which opacifier is added, is only one third of that obtained with the pure melt, is probably due to one of the following causes. Either the fine particles of opacifier act as centres of crystallisation for the depositing fluorides even during normal firing, or the separation of fluorides is accelerated by the partial dissolution of the opacifier in the melt. The latter explanation is less probable, since according to Andrew, Clark and Alexander[8] the solubility of fluorides in an enamel mixture is raised by melting-in stannic oxide.

In practical working, this phenomenon of the increase in opacity on after-firing, due to ageing of the enamel, can seldom be observed, since the firing times are so long compared with laboratory conditions that probably the separation of the fluorides from the supersaturated solution is completed during the normal time of firing. Nevertheless, even in the enamel industry such ageing is known. To-day it is not contested that enamel objects increase in opacity on standing for years. The same phenomenon occurs at elevated temperatures in such short times as to be noticeable and capable of measurement. It is encountered, moreover, in somewhat less noticeable form, with powder enamels also. By overburning enamel B, stannic oxide is again pre-eminent among technical opacifiers in respect of opacification and lustre. As far as opacification is concerned, it is indeed exceeded here also by cerium oxide, but amply makes up for this apparent lack in that stannic oxide enamel, in contrast to enamels with cerium oxide, shows no boiling-out effects.

Lang, in "Glashütte," has recently advocated enamels pre-opacified with antimony trioxide. The dangers which may arise from the use of such enamels for vessels used for the preparation and storage of foodstuffs have already been pointed out. Here only the opacity conditions arising from the use of stannic oxide and cerium oxide will be discussed. The enamel C, pre-opacified with antimony trioxide and melted according to the directions of Karmaus,[17] already possesses an opacity of 73 per cent. when fired alone. This is raised to 80.6 per cent. by the addition of 2.2 per cent. of stannic oxide, at which it remains with 4 per cent. addition also. The same opacification of 80.9 per cent. is obtained also with 2 per cent. of cerium oxide. On overburning, slight mottling of the enamel occurs without addition of opacifier. The enamels mixed with 2 or 4 per cent. of stannic oxide, or 2 per cent. of cerium oxide show, on the other hand, a decrease in opacity of 3.4 per cent. with stannic oxide and 4.7 per cent. with cerium oxide. The latter again shows a slight tendency to boiling out.

To conclude the consideration of the effect of opacifiers on sheet enamel, the lustre must be considered also. This may be measured by the so-called relative lustre number, which is given by the difference in the value of the reflected light with the test piece horizontal and inclined at 45 deg. Here the differences are far less marked than with the opacity. Nevertheless, stannic oxide again stands among the best opacifiers; only "Z" and cerium oxide exceed it somewhat. With "Z" the higher lustre is at once comprehensible since here a different—in fact, transparent—enamel was used, which possesses no surface segregations, as does pre-opacified enamel, and thus shows a directed reflection and surface undistorted by random crystal deposits. Both opacifiers lose this initial superiority in lustre immediately if the test pieces remain in the fire even a short time longer, as is unavoidable in practice. Stannic oxide, on the other hand, retains its lustre very well on overburning, and thus again stands indubitably at the head of the opacifiers.

With enamel C practically the same opacity values and lustre numbers resulted from the use of both stannic oxide and cerium oxide. The values are the same on overburning. The slight deficiency of cerium oxide may remain without comment. Here apparently the enamel itself also determines the magnitude of the lustre effect, just as the pre-opacification contributes the bulk of the opacity. The small additions of opacifier cannot bring about any considerable differences in opacity and lustre. Lang, in "Glashütte," has recently used the expression "Glanzbildner" (lustre producer). It is difficult to understand what this word signifies as applied to an opacifier. The bearer of the lustre is surely the enamel alone, the lustre of which depends on the magnitude of its refractive index. One could only speak of a "lustre producer" if the substance so denoted dissolved in the enamel and so raised its refractive index, so that a larger proportion of the incident light was reflected from the enamel-air interface in accordance with Fresnel's law. Such an augmentation of lustre could arise only from partial dissolution of the opacifier, which is generally to be avoided since it lowers the opacity and, through the gas evolution usually occurring on dissolution, opens the way for the undesirable later phenomena of the development of foam structure and "boiling out."

Influence of Opacifiers on Dry Enamel

Only two opacifiers come into question for the dry process—stannic oxide and antimony oxide, or the antimonates. The necessity of fusion automatically excludes all mixed opacifiers, since these introduce uncontrollable risks into the process. Further, all media acting by gas opacification are excluded. In view of the above experiments it seemed of interest to examine briefly at least the conditions obtaining with powder enamels. For this investigation three enamel powders were fused, using stannic oxide and sodium meta-antimonate in the form of preparations of the "Y" type. The powder mixture chosen consisted of:—Quartz, 10.0; felspar, 22.0; borax, 30.0; potassium nitrate, 8.4; marble, 5.5; cryolite, 2.5; fluorspar, 3.0, and zinc oxide, 11.0, into which in turn 11 parts of stannic oxide, two of the "Y" type were fused, using an electric furnace at 1,100 deg. C. as before. The melts were poured into water, and the dried granules ground to a fineness of 900-mesh in the porcelain ball mill. The stannic oxide powder granules showed a

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greyish-blue tint, both the antimony oxide powders a pale reddish yellow. The powders were dusted on at 850 deg. C.: for the opacity and lustre measurements on the same plates as for wet enamel; for the bending tests, on the metal strips measured previously; and for the acid-resisting experiments, on the test tubes described. There is little practical significance in carrying out bending tests on powder enamels, since such enamels are never subjected to bending. The tests are valuable, however, in that they give at the same time a general idea of the mechanical properties, and so make possible a comparison of the three powder enamels in this respect. The bending experiments were again carried out on the Amsler machine.

It appeared that the bending strength of the three powder enamels was practically the same. All broke with a load of 48 to 50 kg. and a deflection of 20 to 22 mm. With individual specimens breakage occurred only after standing for a short time under this maximum load. The powder

TABLE Va.—*Opacity and Lustre, Enamel B.*

Opacifier.	Per cent. addition to mix.	Normally fired enamel. Opacity per cent.	Relative lustre number.	Mean lustre number.	Overburned enamel. Opacity per cent.	Relative lustre number.	Mean lustre number.	Difference in opacity.	Mean.
—	0	33.0	26.3	26.3	55.1	24.8	24.8	− 22.1	−22.1
SnO_2	2	55.3	29.1	—	60.4	27.1	—	− 5.1	—
,,	6	62.7	39.7	36.9	67.4	28.9	29.2	− 4.7	− 5.3
,,	10	67.7	42.1	—	73.8	31.6	—	− 6.0	—
"W"	2	50.8	26.8	—	58.8	20.8	—	− 8.0	—
,,	6	57.6	34.0	32.7	65.0	23.0	23.8	− 7.4	− 7.1
,,	10	64.9	37.1	—	70.9	26.0	—	− 6.0	—
"X"	2	42.7	23.2	—	56.3	23.2	—	− 13.6	—
,,	6	55.4	29.4	28.6	58.6	24.8	25.1	− 3.2	− 7.1
,,	10	60.0	33.6	—	64.5	27.3	—	− 4.5	—
"Y"	2	49.4	wavy		58.4	23.0	—	− 9.0	—
,,	6	56.5	wavy		63.7	24.8	25.1	− 7.2	− 7.3
,,	10	61.2	35.3	35.3	66.8	27.4	—	− 5.6	—
CeO_2	2	63.6	42.6	42.4	66.8	27.5*	28.5	− 3.2	—
,,	4	75.2	42.2	—	74.4	29.6*	—	0.8	—
Enamel C.									
—	0	73.0	wavy		74.7	35.0	35.0	− 1.7	—
SnO_2	2	80.6	wavy		77.0	32.8	34.2	3.6	3.4
,,	4	80.6	32.4	—	77.4	35.6	—	3.2	—
CeO_2	2	80.9	31.9	—	76.2	36.2*	—	4.7	—
Powder enamel.									
SnO_2	—	77.9	—	55.7	82.3	—	30.7	− 4.4	—
"Y"	—	77.7	—	54.5	84.5	—	29.4	− 6.8	—
,,	—	77.9	—	54.7	84.0	—	31.8	− 6.1	—

* Enamel somewhat foamy.

enamels were thus equal in this respect. The chemical resistance of the enamel was tested by boiling with 1 per cent. acetic acid for 1 hr., and for the opacity and lustre determinations the Ostwald half-shade apparatus was employed. The acid extraction experiment yielded also almost identical figures for all three powder enamels (about 130 to 140 mg./50 sq. cm.). The two antimony oxide powders were exactly equal in solubility with 128.7 and 128.8 mg. The solubility of the stannic oxide powder was rather higher, with 138.0 mg. (see Table IV).

The opacity and lustre measurements again present an interesting picture. They gave an opacity of 77.7 to 77.9 per cent. for all three powders (see Table Va), and a relative lustre number of 54.7 to 55.7, *i.e.*, an almost complete agreement of opacity and lustre. The colour tone of the three powders was admittedly somewhat different. It should be stated further that the amount of powder fired on to the individual plates was, of course, weighed; it varied between 24.5 and 25.5 grm. with the different test plates. On overburning, the ageing phenomenon associated with an increase in opacity again showed itself. When held for a long time at the melting temperature the enamels come to equilibrium, with the deposition of still dissolved opacifier, with which an increase in opacity is again associated. Although little perceptible visually, this ageing phenomenon led in all cases to a uniform decrease in lustre. The relative lustre number decreased to 29.4 to 31.8. The resistance of the stannic oxide to the reducing influence of the iron in these experiments must also be referred to. On overburning, the ground enamel blackened round the raised rim of the test plate, so that the iron and covering enamel could enter into reaction. This was shown in the case of the antimony powders by a black edging about 1 mm. broad, which was absent in the case of the stannic oxide powder. Stannic oxide is thus very stable towards reduction, and it is improbable that the black spots which occasionally occur in powder enamels are attributable to a reduction of the stannic oxide. The above observation may serve also as a corroboration of the views of Karmaus and Vielhaber, according to which the so-called dirty spots in enamel are not due to reduction of stannic oxide, but to other causes.[11]

In the book, "Die Emailfabrikation," the author has several times referred to the increase of opacity with age, which is once more confirmed by the above. This reference was then, however, based almost entirely on theoretical grounds. Kraze[9] has already suggested that, with the aid of this phenomenon, a degree of opacity which by itself was insufficient could be satisfactorily corrected by heating the piece several times to a dull red heat. As may be seen from the figures given, this additional opacity by ageing is about 10 per cent. of the total opacity. This increase would in most cases be still insufficient to raise an intrinsically bad opacity to a satisfactory level.

Of great importance, however, is the recognition that by good firing an increase in opacity occurs with many enamels. The extent of this will always be different in the individual case, and will depend on the time and temperature of firing, etc. It is an open question whether in technical practice—for example in the repeated firing of enamelled baths—such increases in opacity are actually observed, as one might assume from the statement of Kraze. It is probable that in the long time available for the enamel during normal firing, the attainment of equilibrium proceeds far, and that the maximum opacification is attained. That such after-crystallisations can take place during the large-scale use of the powder process has already been shown in the manufacture of baths with a brand of Zirconium powder.

Summary and Results

The influence of several opacifiers on the mechanical, thermal, chemical, and optical properties of both wet and dry enamels has been investigated. The investigation covered stannic oxide in both pure and admixed form, mixed opacifiers, meta-antimonates, cerium oxide and gas opacifiers.

It has been established that the firing of the enamel with the various opacifiers is not a process which is confined to a simple enveloping and penetration of the opacifier particles, with occasional dissolution and vitrification of the same. In spite of the short time of firing, processes occur in the enamel which fundamentally change its nature and properties. Clearly, these processes must move in the direction of the attainment of equilibrium in the heterogeneous system, and in the sense of a decrease in the free energy of the system. How far we assist or suppress this tendency towards the attainment of equilibrium is a matter on which depends to a great extent the technical and economic success of the enamelling.

This attainment of equilibrium may occasionally proceed discontinuously. Opacification especially is a process which frequently develops in steps. The final effect results from the co-operation of opacifiers with pre-opacification. The pre-opacification is not infrequently, however, first developed during firing with the opacifier and under the influence of the latter, and indeed often extends far into any post-firing period. This slow attainment of equilibrium, with deposition of dissolved opacifying material, such as fluorides or antimony trioxide or the fused-in opacifier (as in the case of the powder enamels) can be followed experimentally. It is also the cause of the increase in opacity of enamelware on standing, which has already been frequently mentioned in the literature.

Of the opacifiers, stannic oxide on the whole exerts the most far-reaching and favourable influence on the properties of the enamel. With respect to improving the coating power of the slip, and the mechanical, thermal and chemical properties of the enamel, it holds indisputably the foremost position. Its action is most favourable when it is used pure and unmixed. Added materials may considerably or completely suspend the effect of pure stannic oxide upon certain properties.

By reason of this favourable action of stannic oxide on the properties of the enamel, a certain slight solubility in the enamel melt, which certainly exists, and the vitrification which thereby results, appear in quite another light. The action of stannic oxide is usually considered from a purely optical point of view only, and the solubility regarded as a source of loss. On the basis of the results obtained above, that is not the case. In exchange, a number of improvements are obtained in the enamel itself, which can easily bear a slight loss of opacity. This vitrification loss occurs with other opacifiers also, but the compensating improvement of the enamel obtained is much smaller, or is absent, or even negative.

As far as the optical effect is concerned, there also the unconditional superiority of stannic oxide must be advanced. The opacity produced by it is the strongest of the technical opacifiers. Although it is on occasion exceeded by cerium

(*Concluded on page* 188.)

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The Week's News in Brief

Trade Talk

JOSEPH L. THOMPSON & SONS, LIMITED, of Sunderland, have received an order for a 9,500-ton cargo ship for British owners.

CRAVEN BROS. (MANCHESTER), LIMITED, are making extensive alterations at their Vauxhall Works at Reddish, near Manchester.

THE ANGLO-AMERICAN OIL COMPANY, LIMITED, has ordered two oil-tankers of 6,500 tons from the Furness Shipbuilding Company, Limited, Haverton Hill-on-Tees.

THE MINISTRY OF LABOUR CONCILIATION DEPARTMENT may intervene in the dispute at the works of the Forth & Clyde Steel Foundry (1932), Limited, Kirkintilloch, where a strike of the labourers for standard wages has led to a general stoppage.

IN ORDER TO extend their sales of oil engines, lighting plant and agricultural equipment in Ireland, R. A. Lister & Company, Limited, of Dursley, Glos., have opened offices and service depôts at 44, South Dock Street, Dublin, and 40, Victoria Square, Belfast.

THE UNITED ENGINEERING & FOUNDRY COMPANY, of Pittsburgh, has received a contract for a continuous strip mill for Richard Thomas & Company, Limited, to be installed at Ebbw Vale. It is understood that the contract represents a figure of $5,000,000 (approximately £1,000,000), over half of which is to be spent in this country.

THERE IS A PROSPECT that a new industrial undertaking will be started at Jarrow. A London firm are stated to be interested in the big boiler shop at Palmer's works for a metal foundry. Last week, Jarrow Town Council, at a special meeting, considered the schemes of possible new works in the town with a view to sending them to the Government.

EXTENSIVE RE-EQUIPMENT is proceeding at the Balbardie Steelworks of the North British Steel Foundry, Limited, Bathgate. During the past 12 months the fettling shop has been entirely re-equipped with high-speed grinding machines, and two new sand-blast units are now being completed. Up-to-date dust-arresting plant is provided. In the foundry a composite sand-preparation plant is awaiting erection, which will be capable of treating 50 tons of facing sand per day.

WORK AT the South African Iron & Steel Industrial Corporation's works in connection with the extensions to the blast-furnace plant and additional hot-blast stoves is proceeding rapidly. The extensions consist of the addition of a second blast furnace similar to the original blast furnace installed, and also the provision of two more hot-blast stoves. The charging arrangements are of the most modern mechanical type, and will be under the control of one man. The coke and ore elevating skip will receive the charge from an extension to the existing concrete ore bins through a measuring hopper.

THE EMPLOYMENT of trainees in the engineering industry was discussed at a conference in London, last week, between the Amalgamated Engineering Union and the Engineering & Allied Employers' National Federation. The conference was of an explanatory nature and it was agreed that it should stand adjourned to enable both sides to give further consideration to the questions. The union, it is stated, does not admit that there is a definite scarcity of skilled labour, or that there is any urgent need to introduce trainees. The employers, it is believed, have offered to give consideration to the absorption of the union's unemployed members, numbering over 8,000.

Opacifiers in Wet and Dry Enamels

(*Concluded from page* 186.)

dioxide, this is more than compensated for by the fact that the stannic oxide opacification is the most stable towards firing, and stands the prolonged overfiring without damage, especially without becoming foamy or "boiling out." This property of heat stability is an indispensable requirement of any technical opacifier, and in a well conducted works is the decisive factor conditioning a reduction of the reject-quota, thus deciding the level of economic success. What has been said of the opacity applies equally to the lustre of the enamel. Here also the superiority of stannic oxide is based not only on the grade of the gloss produced by normal firing, but above all on the great stability which the stannic oxide enamel shows on long standing of the ware in the furnace, and by the somewhat uneven firing in different parts of the furnace, which is inevitable in practice. This investigation has thus confirmed, firmly established, and extended the old experience that stannic oxide represents the best universal opacifier yet known to the enamel industry. The ease of its application and the trustworthiness of its opacification, in addition to the newly discovered favourable influences it confers on the enamel in physical and chemical respects, ensure for it even to-day the leading place among opacifiers.

In connection with the above work the author acknowledges financial grants from the Union Veronese and the International Tin Research and Development Council.

Company Meetings

William Baird & Company, Limited

Presiding at the annual meeting of William Baird & Company, Limited, held in Glasgow on August 26, MR. R. L. ANGUS (chairman) said that, unless Scotland could obtain the same facilities for disposing of coke-oven gas as in other districts in England and abroad, it was impossible for them to produce pig-iron at anything approaching competitive prices. The question of the modernisation of the company's blast furnaces had meantime been further delayed until it was known whether a market for the gas would be available.

Brightside Foundry & Engineering Company, Limited

The annual meeting of the Brightside Foundry & Engineering Company, Limited, was held in Sheffield on August 24. MR. FREDERICK W. FIRTH (chairman), presiding, said that the balance-sheet showed a satisfactory result and undoubtedly the profit earned was due largely to an exceptionally big turnover. Their previous policy of keeping plant up to date had enabled the company to benefit by economies in production, and while increased selling prices had improved the turnover, in many cases such increase had only covered the extra cost of materials and wages. Their wages bill was nearly 20 per cent. higher as compared with the previous financial year. The board had transferred a large sum to reserve account, following the conservative policy adopted over many years. In addition, the usual depreciation had been made in their accounts on plant and buildings. The demand for chilled, grain, and alloy rolls had continued to increase during the year, and Mr. Firth added that their heavy foundry had, during this period, produced two of the largest castings ever made in this country. They had also dealt with a record number of heating, ventilating, and air-conditioning installations throughout the country and abroad. In view of the very satisfactory condition of their order-book it had been necessary for the board to sanction further additional expenditure on extensions and improvements, and so put them in a position to meet the increased demands made upon them. The issue of new shares was made with a view to meeting part of this required expenditure.

Company Reports

Ransomes & Rapier, Limited.—Interim dividend of 2½ per cent., free of tax, on the ordinary shares.

R. & W. Hawthorn, Leslie & Company, Limited.—Dividend for the year ended June 30 of 6 per cent.

Wallsend Slipway & Engineering Company, Limited.—Interim dividend of 3 per cent. on the ordinary shares.

Qualcast, Limited.—Final dividend of 10 per cent. and a 5 per cent. cash bonus, making 20 per cent. for the year ended June 30.

Personal

MR. W. W. KINNIBURGH, for 27 years foreman patternmaker with the Shotts Iron Company, Limited, will shortly retire.

MR. JAMES BRUCE JONES, director of Jones & Campbell, Limited, Torwood Foundry, Larbert, was married to Miss Dorothy Jean Stephenson last Saturday.

MR. K. MATHON has been permitted to resign his position as chairman of the board of management of the Mysore Iron and Steel Works at Bhadravathi, with effect from August 1. Mr. A. V. Ramanathan, chief secretary to the Government of Mysore, has been appointed chairman in his place, and is also taking control of the Mysore Government Porcelain Factory and the Government Electrical Works.

MR. V. G. PEARSON resigns his position on the executive staff of Edgar Allen & Company, Limited, this month to take up an appointment with Welding Rods, Limited, of Greenland Road, Sheffield, 9. Mr. Pearson is a recognised authority on electric welding, and has read Papers on the subject before a number of the scientific societies; he contributed a Paper to the recent Welding Symposium organised by the Iron and Steel Institute. During the last 18 years he has devoted particular study to the application of welding in the steel foundry industry. His practical and theoretical knowledge will be available to engineers confronted with welding problems and his experience on the foundry side will be of particular interest to the foundry trade.

Wills

PAGETT, W. W., of Kingswinford, Staffs, ironfounder	£47,901
OSBORN, W. F., chairman of Samuel Osborn & Company, Limited, Clyde Steelworks, Sheffield, director of High Speed Steel Alloys, Limited, of Widnes, Master Cutler in 1906 ...	£171,588

Obituary

SIR RAMON DE LA SOTA, steamship and iron-ore mine-owner, died on August 17, at his residence in Las Arenas, Bilbao, Spain.

THE DEATH HAS OCCURRED of Mr. John Wood, iron and brass founder, of Garden Street, Ramsbottom, Lancs. He commenced his first foundry at Kay Brow, Ramsbottom, in 1881, and removed to Garden Street in 1896. He was 86 years of age.

MR. WILLIAM RINTOUL, until recently a director of research in Imperial Chemical Industries, Limited, died on August 24 at Ardrossan, Ayrshire, at the age of 66. Mr. Rintoul received his training in Glasgow. In 1894 he was appointed a chemist in the Royal Gunpowder Factory, Waltham Abbey, and in due course he rose to the position of chief chemist, but after 15 years' service with the Government left to join the staff of Nobel's Explosives Company, Limited (now merged in Imperial Chemical Industries), where he remained until his death. He started with the Nobel Company as chief chemist, and later on he became research manager at their Ardeer factory. About 10 years ago he was removed to the headquarters of Imperial Chemical Industries as a manager of their research organisation. He served on the Councils of the Chemical Society and the Institute of Chemistry, and when he died was President of the Faraday Society. He was a member of the Safety in Mines Research Board, member of the Chemistry Research Board, and member of the Science Museum Advisory Council.

Applications for Trade Marks

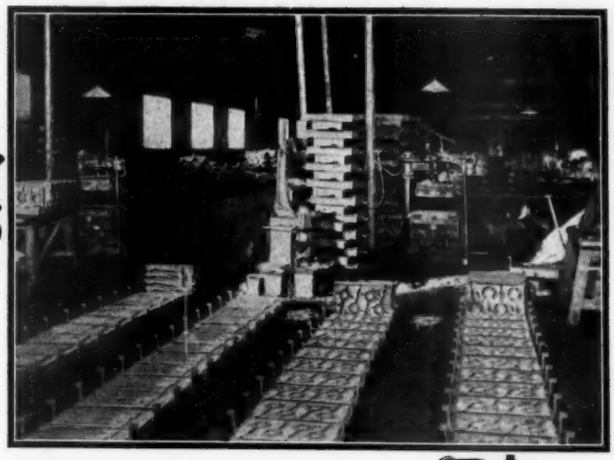
The following list of applications to register trade marks has been taken from the "Trade Marks Journal":—

"TEMRITE."—Metal goods. Murray Engineering & Foundry Company, Limited, 42, Lower Road, Rotherhithe, London, S.E.16.

"I.V.E." AND DEVICE (CERTIFICATION MARK).—Vitreous-enamelled articles of ordinary metal. Institute of Vitreous Enamellers, Limited, 49, Wellington Street, Strand, London, W.C.2.

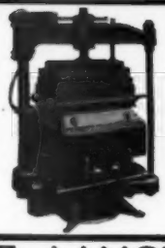
B.I. MAGNETIC MOULDING MACHINES

BRITISH PATENTS 321777, 322720, 349173, 355809



Each machine forms a complete unit.
Construction and control are simple.
Operating costs are very low. Power is only used during the squeeze operation—approx. 2 seconds. Upkeep costs are very small. There are few moving parts, no glands or packings, and no troublesome pipe lines.
If only A.C. is available, a relatively small A.C./D.C. convertor is required. A sequence relay device allows of operating a battery of machines from one convertor. Electric vibrators and heaters can be supplied if required. All parts are efficiently guarded against ingress of sand. The illustration shows B.I. Magnetic Moulding Machines installed in the foundry of Messrs. Stoves Ltd., Rainhill, Lancs.

THE ONLY MOULDING MACHINES IN THE WORLD WHICH UTILISE ELECTRICITY AS THE DIRECT POWER MEDIUM FOR HIGH PRODUCTION WORK.



BRITISH INSULATED CABLES LTD., PRESCOT, LANCS.
Tel. No. Prescot 6571. *London Office*, Surrey House, Embankment, W.C.2. Tel. No. Temple Bar 4793, 4, 5 & 6.

WARNER *Special* PIG IRONS

- *Warner C.B.R.*
  and
- *Low Carbon Cylinder*
  (FOR CYLINDERS, ROLLS, ENGINEERING CASTINGS, ETC.)
- *Low Carbon Malleable*
  (FOR MALLEABLE CASTINGS OF ALL DESCRIPTIONS)

Supplied to any specification between limits of 2·00 and 3·50% Carbon and ·50% and 3·50% Silicon

ACTUAL ANALYSIS CERTIFICATES ARE AVAILABLE WITH EACH DELIVERY

● **Typical Cylinder Pig Iron Specification**

TOTAL CARBON	2·70%
SILICON	1·80%
MANGANESE	·90%
SULPHUR	·06%
PHOSPHORUS	·40%

● **Typical Malleable Pig Iron Specification**

TOTAL CARBON	2·60%
SILICON	·75%
MANGANESE	·50%
SULPHUR	·05%
PHOSPHORUS	·06%

WARNER & CO., LTD
CARGO FLEET MIDDLESBROUGH

Raw Material Markets

Prospects for the iron and steel industry up to the end of the year are very satisfactory, and production figures are likely to be at record levels. No lightening of the pressure for deliveries is to be expected, as home consumers undoubtedly still have heavy requirements to be satisfied. On the export market, too, specifications are on an increased scale. Anxiety is being caused to makers of hematite owing to the continuance of the Spanish civil war, for supplies of ore are likely to become short. Hematite producers, however, have announced that they are now willing to enter into contracts involving deliveries up to March 1, 1937.

Pig-Iron

MIDDLESBROUGH.—There have been many contracts made for the supply of pig-iron over the first few months of next year. Users are all well employed and are persistent in their pressure for deliveries. Owing to the rising costs of production ironmasters are reluctant to commit themselves too far ahead. Local steelworks continue to take up large tonnages. Inquiries from overseas consumers are large, but only a comparatively small proportion of these can be accepted. No. 3 Cleveland G.M.B. is quoted at 75s. per ton for delivery in Middlesbrough and Falkirk districts, 77s. on the North-East Coast, and 78s. in Scotland.

Hematite makers are still hard pressed for deliveries from home consumers, but they are endeavouring, with only limited success, to maintain contact with their overseas users. Only small tonnages have been despatched abroad at about 75s. per ton f.o.b. Home minimum prices are 85s. per ton for East Coast mixed numbers delivered on the North-East Coast, 82s. 6d. c.i.f. South Wales, 90s. 6d. in Sheffield, and 96s. in Birmingham, less 5s. rebate.

LANCASHIRE.—The demand for deliveries against existing contracts is increasing, but new business does not amount to any substantial tonnage. Stocks at most of the consuming works are fairly high, but renewed activity in the placing of new contracts may soon be looked for. Satisfactory employment exists with light-castings makers, the heavy electrical engineering concerns, and also with the machine-tool makers. Users of special irons and general engineers are taking up pig-iron regularly. Staffordshire and Derbyshire brands of No. 3 foundry iron are quoted at 83s. per ton for delivery in the Lancashire price zone, with Northants at 81s. 6d. For delivery in the Manchester district Scottish No. 3 iron is on offer in the region of 91s., a fair number of inquiries being received. The hematite market maintains its firm tone, with West Coast material offered at about 93s. 6d. per ton and East Coast at 93s., both delivered equal to Manchester.

MIDLANDS.—Pig-iron consumers are endeavouring to build up stocks in view of the fact that supplies are likely to become difficult to procure in the autumn. Makers, at the present time, are being compelled to augment their deliveries with supplies from their small stocks, and they are not eager to increase their commitments. The Association minimum prices delivered Birmingham and Black Country stations are 77s. 6d. per ton for Northants No. 3 and 80s. for Derbyshire, Lincolnshire and North Staffordshire No. 3, subject to a small sliding-scale rebate to large users. Forge pig-iron is still quoted at 5s. per ton below the foregoing prices, with a shortage of supplies of some grades. Consumers of the special irons are very active and are taking up substantial tonnages. Prices vary according to analysis and railway rate and are as follow:—Medium-phosphorus, 82s. 6d. to 90s.; low-phosphorus, including Scottish, 92s. 6d. to 100s.; refined irons, £6 10s. to £8 10s. As a result of the decision of hematite makers to accept business for deliveries up to the end of February of next year, many producers who were off the market have now become sellers again. The pressure for deliveries continues unabated. Prices are controlled, and for delivery to South Staffordshire station are £4 17s. for West Coast mixed numbers, £4 16s. for East Coast No. 3, and £4 15s. for Welsh mixed numbers, subject to 5s. rebate where applicable, and plus 1s. 6d. per ton if delivered into works.

SCOTLAND.—Firm conditions continue to prevail on the Scottish pig-iron market. The official prices are unchanged at 81s. 6d. for No. 1 and 79s. for No. 3, f.o.t. furnaces. The official quotations of No. 3 Cleveland are 75s. f.o.t. Falkirk and 78s. f.o.t. Glasgow. Deliveries are on a satisfactory scale. The steelworks remain heavy consumers of both hematite and basic. Imports of basic from India have amounted to a considerable tonnage, but all is required in order to cope with the heavy demand made upon home-produced material. Prices of steel-making irons remain at 85s. 6d., less 5s. rebate, for mixed numbers of East Coast, West Coast and Scottish hematite, and 75s., less 5s. rebate, for British and Indian basic, all delivered steelworks here.

Coke

Owing to the exceptionally heavy requirements of coke consumers some makers are limiting the amount that can be despatched to individual buyers. For delivery in Birmingham and district, best Durham foundry coke is quoted at 40s. 6d. to 42s. 6d., and Welsh from 39s. 6d. up to 50s., according to quality.

Steel

Busy conditions rule in all departments of the steel trade, and although most of the production is absorbed by the home market, inquiry upon export account has recently become more active, states the official report of the London Iron and Steel Exchange. With the closing of the holiday season, specifications are reaching the steelworks in greater volume, and the resources of the manufacturers are being severely taxed to meet their customers' requirements. The demand for British semi-finished steel shows no sign of declining, and although the works are operating at capacity, the production is passing into immediate use. In the finished steel section of the market business has been maintained at a high level throughout the holiday period, and is now showing signs of the usual seasonal expansion. In view of the amount of work the makers have already booked, the time required for the execution of orders is becoming more extended.

Scrap

On the Cleveland market deliveries of heavy melting steel at 57s. 6d. per ton are still being limited and sellers are reluctant to contract for forward delivery. Foundry cast iron is firm at 62s. 6d. and more has been paid, while machinery metal is firmer at 65s. to 67s. 6d. Business on the South Wales market is brisk. Heavy steel scrap in furnace sizes receives a large inquiry at 62s. to 63s., while mixed wrought-iron and steel scrap for basic furnaces is at 59s. to 60s. and some good tonnages have changed hands. Good cast-iron machinery scrap in foundry sizes has a limited local inquiry at 62s. to 64s. There continues to be some heavy buying on the Midlands market and prices are firm. Heavy unsheared wrought iron is at 65s., but only a small tonnage is taken up. Short, heavy steel, as used in the foundries, is at 65s. per ton delivered works. Steady conditions continue to dominate the Scottish market. Heavy machinery cast-iron scrap is at 67s. 6d. to 69s., in pieces not exceeding 1 cwt., while ordinary cast iron, to the same specification, is at 64s. to 65s. per ton, delivered f.o.t. consumers' works.

Metals

Copper.—The weekly market report issued by Henry Gardner & Company, Limited, states that during the past week the market has recovered confidence and, after the recent reaction, again wears an optimistic aspect. "The demand for copper continues to be steady and in excellent volume, and it is difficult to see any change in this situation under present conditions. The warlike state of mind of so many nations of the world is continually leading to bigger armaments with all the necessary attendant building and construction, and consequently any decrease in the demand for metals at present seems very unlikely." Only a moderate industrial demand is reported from the United States, and in view of the decision of producers to increase their outputs it is extremely unlikely that any price increase will now occur in the near future.

Daily market prices :—

Cash.—Thursday, £38 7s. 6d. to £38 8s. 9d.; Friday, £38 10s. to £38 11s. 3d.; Monday, £38 6s. 3d. to £38 8s. 9d.; Tuesday, £38 8s. 9d. to £38 10s.; Wednesday, £38 10s. to £38 12s. 6d.

Three Months.—Thursday, £38 12s. 6d. to £38 13s. 9d.; Friday, £38 15s. to £38 16s. 3d.; Monday, £38 12s. 6d. to £38 13s. 9d.; Tuesday, £38 13s. 9d. to £38 15s.; Wednesday, £38 15s. to £38 16s. 3d.

Tin.—The next meeting of the International Tin Committee has been further postponed until Wednesday, September 23. The reason for this, the second extension of dates, must presumably be to allow all the parties concerned to arrive in London for the meeting. Mr. Harry Connell, Siamese Government delegate to the International Tin Committee, interviewed at Penang on Friday, said that they wanted Siam's case to be heard. So far they had not discussed the position with the International Committee. They wanted to be in the discussions, not to be dictated to by certain parts of the Committee. They were asking nothing unreasonable. If restriction went they were all bound to suffer, said Mr. Connell, who hopes to return in October with Siam's share of the world's tin market arranged on a satisfactory basis. Meanwhile, the market has been quiet and featureless. Industrial demand in the United States has continued on a good scale, with the tinplate mills and the motor-car makers particularly active.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £185 10s. to £185 15s.; Friday, £186 10s. to £186 15s.; Monday, £188 15s. to £189; Tuesday, £188 7s. 6d. to £188 12s. 6d.; Wednesday, £187 10s. to £187 15s.

Three Months.—Thursday, £183 to £183 5s.; Friday, £183 12s. 6d. to £183 15s.; Monday, £186 2s. 6d. to £186 5s.; Tuesday, £188 5s. to £188 10s.; Wednesday, £184 10s. to £184 15s.

Spelter.—There is little of importance to report this week, the market having been quiet and uninteresting. High-grade zinc for brass making is well taken up, but otherwise consumers are showing little enthusiasm. Moderate business has been transacted in the United States, where the outlook for the galvanising trade is encouraging. There have been no further developments in the attempt to re-establish the International Zinc Cartel, and it would appear as if producers had lost interest, and while this state of affairs prevails the market is unlikely to have any fresh incentive.

Official quotations were as follow :—

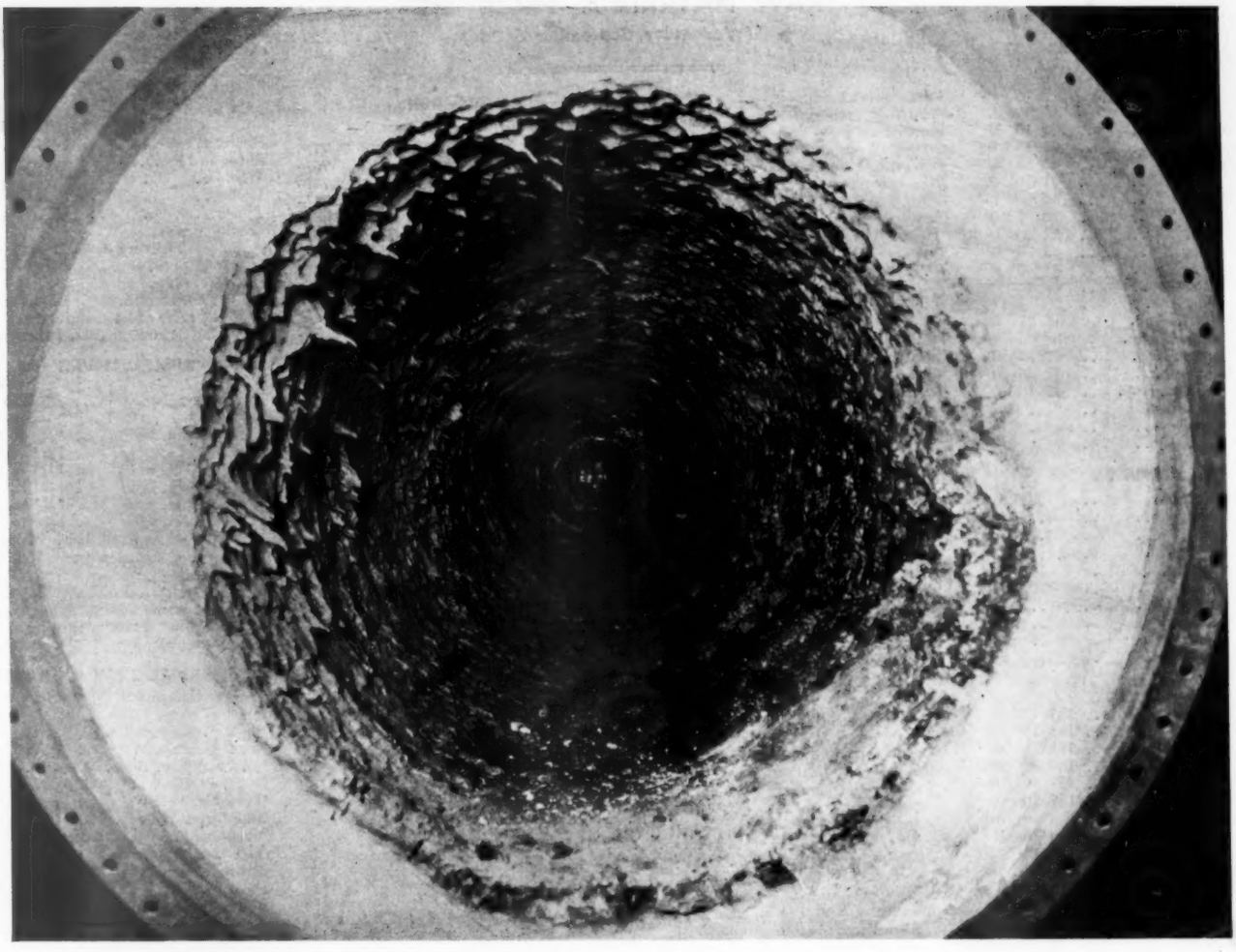
Ordinary.—Thursday, £13 12s. 6d.; Friday, £13 15s.; Monday, £13 16s. 3d.; Tuesday, £13 11s. 3d.; Wednesday, £13 8s. 9d.

Lead.—On August 27 a new high level for lead prices for the current year was established at £17 5s. per ton. This was undoubtedly caused by the stringency in supplies that is now apparent. Consumption is well maintained, while production is hampered by the Spanish civil war and by the strike at Hoboken. However, the Spanish output is only comparatively small compared with what it was. In 1888 Spain produced as much as 234,800 tons, but in 1935 the Spanish output was only 70,566 tons, and during the first half of this year—before the civil war—it declined to 28,070 tons.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £17 5s.; Friday, £17 2s. 6d.; Monday, £17 1s. 3d.; Tuesday, £17; Wednesday, £17 2s. 6d.

WHEN THINKING OF
SANDBLAST
THINK OF
RICHARDSON'S
Established 1887.
We Supply Re-Conditioned & New
SAND BLAST PLANTS
AND
AIR COMPRESSORS.
Tilghman's, Room, Barrel, Chamber, Rotary Table, Dust Arrester, and Continuous Feed Barrel Plants.
Phone: MIDLAND 2281.
Grams: "SANDBLAST, B'HAM."
R. J. RICHARDSON & SONS, Ltd.,
Commercial Street, Birmingham.



950 tons of metal melted—

The above photograph shows the condition of an 04 grade Albino lining in a 5-ton Brackelsberg furnace after 255 heats. You will observe the lining has worn back evenly and it is still approximately 8" in thickness. The 04 grade is specially produced for rotary furnaces, but there are other grades for lining cupolas, converters and ladles. This photograph is reproduced by courtesy of James Howden and Company (Land) Ltd.

ALBINO

ROTARY FURNACE LINING MATERIAL

Please write for further particulars to the sole manufacturers:

GENERAL REFRACTORIES LIMITED,

Genefax House, Sheffield, 10

Telephone: Sheffield 31113 (6 lines) Telegrams: "Genefax, Sheffield"

MANUFACTURERS OF HEAT RESISTING AND HEAT INSULATING MATERIALS OF EVERY DESCRIPTION.

RAW MATERIALS—PRICE LIST

(Wednesday, September 2, 1936)

COPPER

	£ s. d.
Standard cash	38 10 0
Three months	38 15 0
Electrolytic	42 15 0
Tough	41 10 0
Best selected	42 0 0
Sheets	70 0 0
India	52 0 0
Wire bars	43 5 0
Ingot bars	43 5 0
H.C. wire rods	46 15 0
Off. av. cash, Aug.	38 5 11½
Do., 3 mths., Aug.	38 11 3½
Do., Sttlmnt., Aug.	38 5 9
Do., Electro, Aug.	42 13 0
Do., B.S., Aug.	42 5 0
Do., wire bars, Aug.	42 18 6
Solid drawn tubes	10½d.
Brazed tubes	10½d.
Wire	6½d.

BRASS

Solid drawn tubes	9½d.
Brazed tubes	11½d.
Rods, drawn	8½d.
Rods, extd. or rlld.	5d.
Sheets to 10 w.g.	8d.
Wire	7½d.
Rolled metal	7½d.
Yellow metal rods	5d.
Do. 4 × 4 Squares	5½d.
Do. 4 × 3 Sheets	5½d.

TIN

	£ s. d.
Standard cash	187 10 0
Three months	184 10 0
English	187 10 0
Bars	189 12 6
Straits	192 0 0
Australian	187 10 0
Eastern	190 0 0
Banca	190 10 0
Off. av. cash, Aug.	183 17 7½
Do., 3 mths., Aug.	180 17 1½
Do., Sttlmt., Aug.	183 17 0

SPELTER

	£ s. d.
Ordinary	13 8 9
Remelted	13 5 0
Hard	11 15 0
Electro 99.9	15 8 9
English	14 10 0
India	12 15 0
Zinc dust	19 10 0
Zinc ashes	4 5 0
Off. aver., Aug.	13 12 10½
Aver. spot, Aug.	13 10 6¾

LEAD

	£ s. d.
Soft foreign ppt.	17 2 6
Empire	17 15 0
English	19 0 0
Off. average, Aug.	16 16 3¾
Average spot, Aug.	16 15 5¼

ALUMINIUM

Ingots	£100 to £105
Wire	1/3 to 1/4 lb.
Sheet and foil	1/2 to 1/4 lb.

ZINC SHEETS, &c.

	£ s. d. £ s. d.
Zinc sheets, English	24 0 0 to 24 10 0
Do., V.M. ex-whse.	24 0 0 to 24 10 0
Rods	25 10 0

ANTIMONY

	£ s. d. £ s. d.
English	64 10 0 to 65 10 0
Chinese, ex-whse.	54 0 0
Crude, c.i.f.	24 10 0

QUICKSILVER

	£ s. d. £ s. d.
Quicksilver	12 2 6 to 12 12 6

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	8 17 6
45/50%	11 10 0 to 12 15 0
75%	16 12 6 to 17 17 6
Ferro-vanadium—	
35/50%	12/8 lb. Va.
Ferro-molybdenum—	
70/75% carbon-free	4/6 lb. Mo.
Ferro-titanium—	
20/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£21 to £22
Ferro-tungsten—	
80/85%	3/1½ lb.
Tungsten metal powder—	
98/99%	3/3 lb.
Ferro-chrome—	
2/4% car.	33 0 0
4/6% car.	21 10 0
6/8% car.	21 0 0
8/10% car.	21 0 0
Ferro-chrome—	
Max. 2% car.	33 10 0
Max. 1% car.	36 5 0
Max. 0.50% car.	37 5 0
70% carbon-free	9½d. lb.
Nickel—99.5/100%	£200 to £205
"F" nickel shot	£184 0 0
Ferro-cobalt, 98/99%	6/3 to 6/9 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese—	
76/80% loose	£11 5 0 to 11 15 0
76/80% packed	£12 5 0 to 12 15 0
76/80% export	£10 5 0
Metallic manganese—	
94/96% carbon-free	1/3 lb.

Per ton unless otherwise stated, basis 2-ton lots.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 0d.
Finished bars, 18% tungsten	2s. 9d.

Per lb. net, d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to $\frac{3}{16}$ in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅛ in.	3d. lb.
Do., under ½ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£ s. d.	£ s. d.
South Wales—		
Heavy steel	3 2 0	to 3 3 0
Mixed iron and steel	2 19 0	to 3 0 0
Heavy cast iron	2 18 0	to 3 0 0
Good machinery	3 2 0	to 3 4 0
Cleveland—		
Heavy steel	2 17 6	
Steel turnings	2 0 0	
Heavy cast iron	3 2 6	
Heavy machinery	3 5 0	to 3 7 6
Midlands—		
Light cast-iron scrap	2 12 6	to 2 15 0
Heavy wrought iron	3 5 0	
Steel turnings	2 0 0	
Scotland—		
Heavy steel	2 17 6	
Ordinary cast iron	3 4 0	to 3 5 0
Engineers' turnings	2 2 6	
Cast-iron borings	1 17 6	
Wrot-iron piling	3 7 6	to 3 8 0
Heavy machinery	3 7 6	to 3 9 0

London—Merchants' buying prices, delivered yard.

	£ s. d.
Copper (clean)	30 0 0
Brass	19 10 0
Lead (less usual draft)	15 10 0
Tea lead	11 10 0
Zinc	8 10 0
New aluminium cuttings	74 0 0
Braziery copper	28 0 0
Gunmetal	29 0 0
Hollow pewter	138 0 0
Shaped black pewter	105 0 0

PIG-IRON

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	77/6
,, No. 3	75/-
,, No. 4	74/-
Forge No. 4	74/-
Hematite No. 1	85/6*
Hematite M/Nos.	85/-*
N.W. Coast—	
Hem. M/Nos. d/d Glas.	85/6*
,, d/d Birm.	97/-*
Malleable iron d/d Birm.	125/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	77/-
,, No. 3 fdry.	80/-
Northants forge	74/6
,, fdry. No. 3	77/6
,, fdry. No. 1	80/6
Derbyshire forge	77/-
,, fdry. No. 3	80/-
,, fdry. No. 1	83/-
Scotland—	
Foundry, No. 1, f.o.t.	81/6
,, No. 3, f.o.t.	79/-
Cleveland No. 3, Glasgow	78/-
,, ,, Falkirk	75/-
Scottish hem. M/Nos. d/d	85/6*
Sheffield (d/d district)—	
Derby forge	74/6
,, fdry. No. 3	77/6
Lincs forge	74/6
,, fdry. No. 3	77/6
W.C. hematite	91/-*
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	83/-
Staffs fdry. No. 3	83/-
Northants fdry. No. 3	81/6
Cleveland fdry. No. 3	83/-
Dalzell, No. 3 (special)	102/6 to 105/-
Glengarnock, No. 3	91/-
Clyde, No. 3	91/-
Monkland, No. 3	91/-
Summerlee, No. 3	91/-
Eglinton, No. 3	91/-
Gartsherrie, No. 3	91/-
Shotts, No. 3	91/-

* Subject to a rebate of 5s. per ton under certain conditions.

FINISHED IRON AND STEEL

Usual district deliveries for iron; delivered consumer's station for steel.

	£ s. d. £ s. d.
Iron—	
Bars (cr.)	10 10 0
Nut and bolt iron	8 17 6 to 9 7 6
Hoops	11 7 6 and up.
Marked bars (Staffs) f.o.t.	13 0 0
Gas strip	11 7 6 and up.
Bolts and nuts, ¾ in. × 4 in.	16 0 0 and up.
Steel—	
Plates, ship, etc.	9 7 6 to 9 10 0
Boiler plts.	9 17 6 to 10 0 0
Chequer plts.	11 0 0
Angles	9 0 0
Tees	10 0 0
Joists	9 7 6
Rounds and squares, 3 in. to 5¼ in.	10 0 0
Rounds under 3 in. to ⅜ in. (Untested)	9 7 0
Flats—8 in. wide and over	9 5 0
,, under 8 in. and over 5 in.	9 10 0
Rails, heavy	8 5 0 to 8 10 0
Fishplates	12 10 0
Hoops (Staffs)	10 2 0
Black sheets, 24g. (4-t. lots)	12 0 0
Galv. cor. shts. (,,)	14 0 0
Galv. flat shts. (,,)	14 10 0
Galv. fencing wire, 8g. plain	15 0 0
Billets, soft	6 2 6
Billets, hard	7 2 6 to 7 7 6
Sheet bars	6 0 0
Tin bars	6 0 0

PHOSPHOR BRONZE

	Per lb. basis
Strip	10½d.
Sheet to 10 w.g.	11½d.
Wire	12½d.
Rods	11½d.
Tubes	14d.
Castings	12½d.

Delivery 3cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7½
To 15 in. wide	1/1½ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
to 10g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	21.31
No. 2 foundry, Valley	19.50
No. 2 foundry, Birm.	15.58
Basic, Valley	19.00
Malleable, Valley	19.50
Grey forge, Valley	19.00
Ferro-mang. 80%, seaboard	75.00
O.-h. rails, h'y, at mill	36.37½
Billets	30.00
Sheet bars	30.00
Wire rods	38.00
	Cents.
Iron bars, Chicago	1.80
Steel bars	1.95
Tank plates	1.90
Beams, etc.	1.90
Skelp, grooved steel	1.80
Steel hoops	1.95
Sheets, black, No. 24	2.50
Sheets, galv., No. 24	3.20
Wire nails	2.10
Plain wire	2.40
Barbed wire, galv.	2.60
Tinplates, 100-lb. box	$5.25

COKE (at ovens)

Welsh foundry	30/- to 32/6
,, furnace	24/- to 25/-
Durham foundry	24/6
,, furnace	21/6
Scotland, foundry	30/-
,, furnace	25/- to 26/-

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20×14 per box	18/9
,,	28×20 ,,	37/6
,,	20×10 ,,	26/9 to 27/-
,,	18¾×14 ,,	19/6
C.W.	20×14 ,,	15/6 to 15/9
,,	28×20 ,,	33/9 to 34/-
,,	20×10 ,,	22/6 to 22/9
,,	18⅞×14 ,,	15/3 to 15/9

SWEDISH CHARCOAL IRON & STEEL

	£ s. d. £ s. d.
Pig-iron	£6 0 0 to £7 0 0
Bars-hammered, basis	£16 0 0 to £16 10 0
Bars and nail-rods, rolled, basis	£15 15 0 to £16 0 0
Blooms	£10 0 0 to £12 0 0
Keg steel	£25 0 0 to £28 0 0
Faggot steel	£18 0 0 to £23 0 0
Bars and rods dead soft, st'l	£10 0 0 to £12 0 0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 18.16 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

		£ s. d.	
Aug.	27 ..	38 7 6 inc.	3/9
,,	28 ..	38 10 0 ,,	2/6
,,	31 ..	38 6 3 dec.	3/9
Sept.	1 ..	38 8 9 inc.	2/6
,,	2 ..	38 10 0 ,,	1/3

Electrolytic Copper

		£ s. d.	
Aug.	27 ..	42 10 0	No change
,,	28 ..	42 15 0 inc.	5/-
,,	31 ..	42 15 0	No change
Sept.	1 ..	42 15 0 ,,	,,
,,	2 ..	42 15 0 ,,	,,

Standard Tin (cash)

		£ s. d.	
Aug.	27 ..	185 10 0 inc.	50/-
,,	28 ..	186 10 0 ,,	20/-
,,	31 ..	188 15 0 ,,	45/-
Sept.	1 ..	188 7 6 dec.	7/6
,,	2 ..	187 10 0 ,,	17/6

Tin (English ingots)

		£ s. d.	
Aug.	27 ..	185 10 0 inc.	50/-
,,	28 ..	186 15 0 ,,	25/-
,,	31 ..	188 15 0 ,,	40/-
Sept.	1 ..	188 10 0 dec.	5/-
,,	2 ..	187 10 0 ,,	20/-

Spelter (ordinary)

		£ s. d.	
Aug.	27 ..	13 12 6 inc.	2/6
,,	28 ..	13 15 0 ,,	2/6
,,	31 ..	13 16 3 ,,	1/3
Sept.	1 ..	13 11 3 dec.	5/-
,,	2 ..	13 8 9 ,,	2/6

Spelter (Electro, 99.9 per cent.)

		£ s. d.	
Aug.	27 ..	15 11 3 inc.	2/6
,,	28 ..	15 12 6 ,,	1/3
,,	31 ..	15 13 9 ,,	1/3
Sept.	1 ..	15 11 3 dec.	2/6
,,	2 ..	15 8 9 ,,	2/6

Lead (soft foreign, prompt)

		£ s. d.	
Aug.	27 ..	17 5 0 inc.	1/3
,,	28 ..	17 2 6 dec.	2/6
,,	31 ..	17 1 3 ,,	1/3
Sept.	1 ..	17 0 0 ,,	1/3
,,	2 ..	17 2 6 inc.	2/6

Lead (English)

		£ s. d.	
Aug.	27 ..	19 5 0	No change
,,	28 ..	19 5 0 ,,	,,
,,	31 ..	19 0 0 dec.	5/-
Sept.	1 ..	19 0 0	No change
,,	2 ..	19 0 0 ,,	,,

AVERAGE MONTHLY PRICES OF STEEL RAILS

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1921	23 5 0	20 4 0	18 0 0	17 0 0	15 0 0	15 0 0	14 0 0	14 0 0	14 0 0	11 12 6	10 10 0	10 0 0	15 4 3
1922	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 0 0	8 15 0	8 15 0	8 15 0	8 15 0	9 4 2
1923	8 17 6	9 2 0	10 5 0	10 10 0	10 10 0	10 10 0	9 15 0	9 0 0	8 15 0	8 15 0	8 19 0	9 5 0	9 9 10
1924	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 2 6	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 2 3½
1925	9 0 0	9 0 0	9 0 0	9 0 0	8 15 0	8 10 7½	8 10 0	8 10 0	8 10 0	8 4 0	8 0 0	8 0 0	8 11 7½
1926	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 7 6	8 10 0	8 10 0	8 10 0	8 10 0	8 3 11½
1927	8 10 0	8 10 0	8 10 0	8 2 6	8 2 6	8 2 6	8 2 6	8 2 6	8 2 6	8 3 0	8 5 0	8 5 0	8 4 10
1928	8 5 0	8 5 0	8 5 0	8 5 9	8 6 3	8 6 3	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 7 9½
1929	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0
1930	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0
1931	8 9 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 8
1932	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1933	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1934	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1935	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1936	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	—	—	—	—	—	—

AVERAGE MONTHLY PRICES OF EAST COAST HEMATITE AT MIDDLESBROUGH

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1920	220 0	220 0	240 0	260 0	260 0	260 0	260 0	260 0	260 0	260 0	260 0	260 0	251 8
1921	240 0	220 0	180 0	180 0	180 0	160 0	160 0	160 0	137 0	127 6	117 6	104 6	162 2
1922	97 6	91 7½	100 0	98 6	97 1½	94 7	93 6	90 9	89 7	91 10½	93 0	93 2	94 5½
1923	94 6	104 9	122 0	126 10½	122 0	115 3	107 0	98 8½	98 10½	99 1½	100 6½	102 3	107 10½
1924	102 4½	101 3	99 7½	99 0	98 9½	97 4½	95 3½	93 1½	90 7½	88 0	88 4½	88 6	95 2½
1925	87 5	85 9	84 7½	82 6	80 10½	79 3	77 1½	75 7½	75 0	74 3½	74 9	76 0	79 5½
1926	77 3	77 9	77 3½	76 3	77 4½	78 0	79 8½	81 9	83 4½	87 7½	92 6	90 5½	81 7½
1927	90	90 0	86 3½	83 1½	80 6	78 0	76 6	75 4½	75 0	72 9	71 9	71 1½	79 2½
1928	69 7½	69 7½	69 9	70 0	70 0	69 3	68 7½	69 2	70 0	70 0	70 3	71 6	69 9½
1929	71 6	72 0	73 6	74 0	74 0	74 1½	74 9	75 6	76 1½	76 8½	78 1½	79 0	74 11½
1930	78 2½	78 0	76 9	75 0	74 0	72 7½	71 0	71 0	71 0	71 0	70 10½	70 4½	73 3½
1931	70 0	69 0	68 0	66 8½	65 1½	63 4½	62 9	61 1½	65 0	65 0	65 0	65 0	65 6
1932	64 10	64 3	63 6	63 6	63 6	62 7½	62 0	60 6	60 0	59 3	59 0	59 0	61 10
1933	59 0	59 0	59 0	59 0	59 0	59 0	59 0	59 0	59 3	60 7½	62 6	62 6	59 8½
1934*	62 6	65 0	67 6	67 6	67 6	67 6	67 6	67 6	68 0	68 6	68 6	68 6	67 2
1935*	69 0	69 0	69 0	69 0	69 0	69 0	70 1½	71 0	71 0	71 0	71 0	71 0	70 1
1936*	71 0	76 3	77 0	77 0	77 10½	80 6	85 0	—	—	—	—	—	—

* Since March, 1934, delivered works; previously f.o.t. furnaces. NOTE.—Prices of hematite have since July 1, 1936, been subject to a rebate of 5s. under certain conditions.

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